Landscape Metropolis #7 Circular Water Stories

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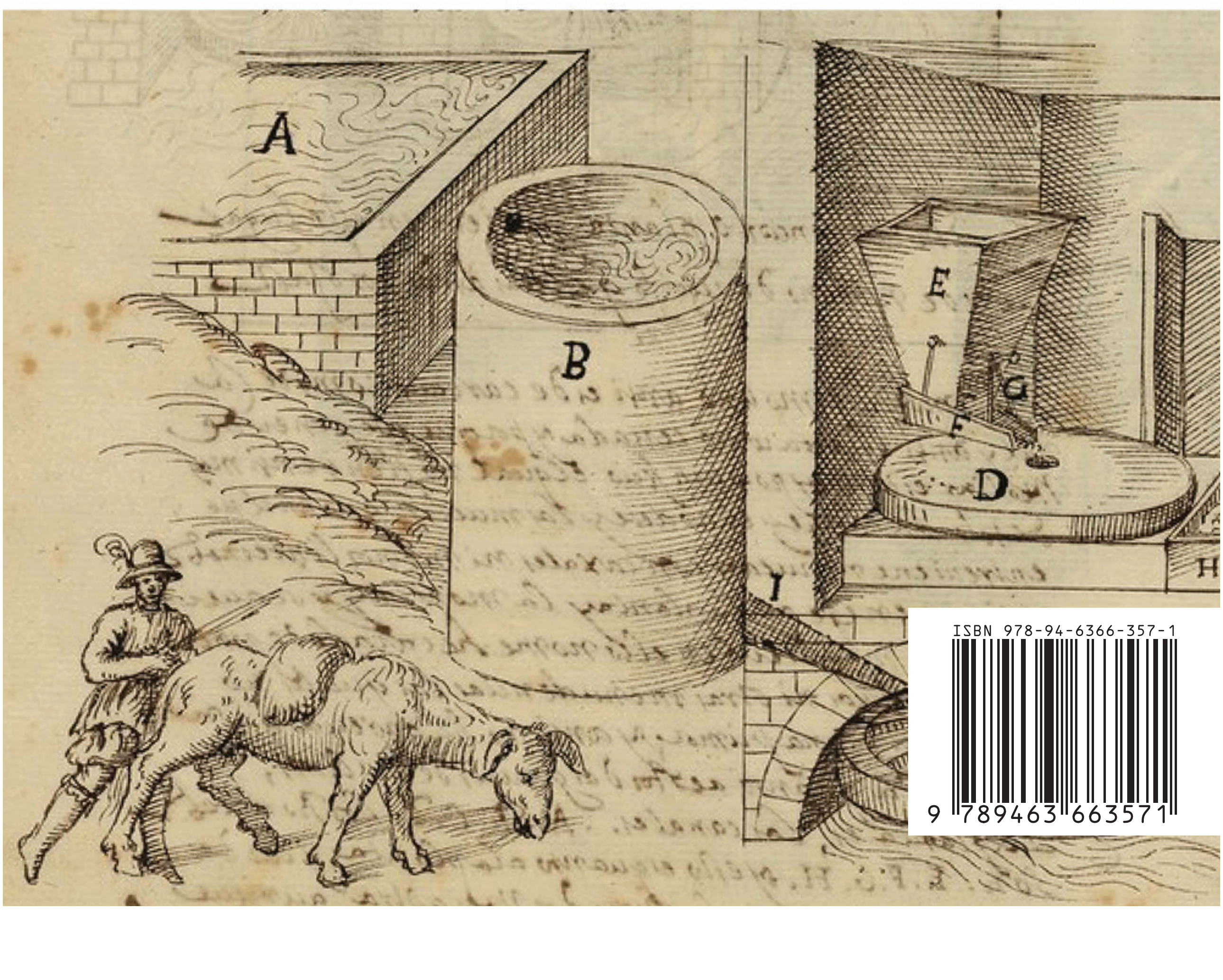

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Landscape Metropolis #7

Editorial

Articles

SPOOL - Journal of Architecture and the Built Environment

SPOOL is a journal initiative in the field of 'architecture and the built environment'. It puts a strong emphasis on specific topics: Science of Architecture; Landscape Metropolis; Energy Innovation, Cyber-physical Architecture and Climate Adaptation. These topics refer to existing and upcoming research programmes/interests in Europe and beyond, and ensure a steady stream of potential copy. Treating these topics as threads within one journal allows SPOOL to focus on the interrelationship between the fields, something that is often lost in specialised journals. SPOOL welcomes within this framework original papers and associated open data on research that deal with interventions in architecture and the built environment by means of design, engineering and/or planning.

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Cover images
Front: Kampung Naga from the main access. Image by Ayu Tri Prestasia.
Back: Bucket mill in the 16th-century manuscript "The Twenty-One Books of Devices and Machines" by Pedro Juan de Lastanosa. Images property of the Biblioteca Nacional de España [Spanish National Library].

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EDITORIAL

Circular Water Stories

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Professional water managers, due to a rise in population, have taken over authority of the living water systems (circular water system) in which there is a self-evident exchange between the natural system and the (human) water chain. This led to an administrative approach to the water system in many - especially western - countries. Water systems were separated into categories like drinking water, drainage, irrigation, sewage systems, and water safety systems, with centralised management. The bond that traditionally existed between communities and 'their' water was literally and figuratively cut off and became not only controlled from the top down, but was also often invisible, amplified by technical innovations or even more disturbingly by a lack of water. This industrialisation caused a change from communities of water workers - aware and knowledgeable about the importance of water as the source of life and shaper of the cultivated landscape - to passive users.

Central to this Spool issue, Landscape Metropolis #7, are contributions that investigate traditional water systems as a source of inspiration for today's challenges. Due to the fact that there are so many interesting contributions there is room for a second issue on: Circular Water Stories Landscape Metropolis #8, which will be published in early 2021.

Few people still know the stories and the discoveries behind indigenous decentralised systems, such as the water mills in the rural area of the Sierra de Cadiz in Spain (page 39), and the Sprengen system in the suburban terrains of the Veluwe in the Netherlands (page 5). Both papers show that it requires research by drawing to discover the workings of these systems in their physical and social context and draw them in such a way that they become visible again in their interaction with the landscape. These systems and their water workers were once drivers and bearers of entire industries and have shaped and structured the landscape and the settlement patterns significantly. As these systems have lost their economic relevance these water systems are considered as relics of the past. This is less true for the traditional Asian gardens of historical cities in Japan (page 23) and absolutely not true for the case of Kampung Naga in Indonesia (page 59), where the community is still actively involved with the water in a circular way, understanding the value of it. Both cases have their own difficulties. In the case of Japan, the governance of the system supported the qualitative and quantitative management of the water. With this traditional organisation lost, the quality and quantity management for the future was hampered. In the village of Kampung Naga (page 59) the community cannot be extended and the way of life is threatened by the growth of the large nearby city and the pollution of the river feeding the water system of Kampung Naga. Knowledge and understanding of traditional organisational systems in this case is crucial for the future. This is why, in the paper on the qanats in Tehran (page 95), the authors focus on mapping the historical development of the participatory management of these waterworks. They highlight the former community-based coordination mechanisms and today's institutional gaps in the management of the qanats. In the case of the maritime backyards of Povoa de Varzim, Portugal (page 77) people are still intensely connected to the water but, due to the upscaling of the fishing industry, the profound knowledge that is hidden in the underwater landscape gets lost. In the visual essay about the Oslo area (page 113), we see examples on how lost water stories can be activated through new design, which keep the memory vivid and at the same time demonstrates how designers can help to face today's climate challenges.

By reading these articles, hopefully everyone can find answers to the question that we asked the authors: What can we learn from traditional water systems in terms of the interaction and engagement between people, water, and the (urban)landscape when building resilient and valuable water landscapes for the future?

We hope you will enjoy the articles and the vast number of images and discover the hidden treasures in these water stories.

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Visual Water Biography

Translating Stories in Space and Time

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Abstract

The supervision of water systems in many countries is centralised and taken over from local water management collectives of 'water workers' by governmental or other water management institutions. Communities are literally and figuratively cut-off from 'their' water systems, due to the increase of urbanisation and industrialisation. On account of water management, humankind changed from communities of actively engaged water workers into passive users. In so doing, crucial knowledge about how communities created, maintained, and expanded 'living water systems', such as rice terraces, low-pasture systems, polders, floating-gardens, brooks-mill, and tidal systems, is rapidly diminishing. Revealing stories (oral accounts) of water workers generate insights and understanding of forgotten aspects of the landscape. They hold information on how to engage with water in a more holistic way, strategies that might help in facing today's challenges. The world in general, but planners, spatial designers, and water managers working with water, in particular, have so far taken little account of these stories. Without documenting stories that are about the dynamic interaction between people and landscape, valuable knowledge has disappeared and continues to do so. To help to overcome this knowledge gap, to learn from the past, the Visual Water Biography (VWB) is developed. The novel method is based on the Delft layer approach in which the spatial relationship of a design and its topography is studied, and developed by many authors from the faculty of landscape architecture at TU Delft in combination with the landscape biography approach. The Visual Water Biography visualises and maps: 1) knowledge and 2) engagement of water workers by focusing on 3) circular and 4) cyclical processes that are descended in the landscape. The method developed for spatial planners, researchers, and designers explicitly allows for multi-disciplinary engagement with water workers, water professionals, people from other disciplines such as historians and ecologists, and the general public. The added value of the VWB method is shown by the case of the Dutch *Sprengen* and Brooks system, a water system that is well documented in terms of landscape biography but less understood as a living water system.

Keywords landscape architecture, living water systems, landscape biography, Delft layer approach, Visual Water Biography (VWB), communities of water workers, transformation, spatial analysis, cyclical and circular processes, *Sprengen* and Brooks system

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Living Water Systems

'[...] no one knows the landscape better than its local communities [...] even if they lack the scientific knowledge for understanding physical and social phenomena [...]'. (Pedroli, 2007)

The Visual Water Biography uses 'research by drawings' to illustrate the stories of water workers, who built, transformed, and maintained landscapes (in the past, some of which are still active today) by using cyclical and circular processes to create living water systems. The drawings show how people adapted their practice and way of life according to the cyclical processes, different series of recurring events and how they integrated and kept natural resources, as long as possible in the system, extracting its maximum value and recovering and regenerating it in the best way.

All over the world, humans lived and worked with the natural water and different grades of wetness between land and water, resulting in the creation of cultural landscapes. Along with the development of civilisation, people have manipulated its [water] function and form, to fulfil their essential needs (Hein et al., 2020). The current worldwide water crisis urges researchers and practitioners to rethink the design and management of our water systems. From a spatial, cultural heritage, and ecological point of view, directed to preservation and/ or reconstruction of landscapes and habitats, the research is moving towards a consensus to learn from traditional water systems to meet today's challenges. The holistic approach towards living systems has gained momentum within 'the interdisciplinary system theory and school of circular economy or circularity'[1]. Within these theories, a 'living system' consists of a cohesive conglomeration of interrelated and interdependent parts which can be natural or manmade, bounded by space and time, influenced by its environment, defined by its structure and purpose, and expressed through its functioning. There is a continual use and reuse of resources to create a 'closed loop', while human and natural interventions boost the regenerative and adaptive capacity of the system (Ellen Macarthur Foundation, n.d.). Acknowledging this need for change in the management of landscapes, the Dutch government urges farmers to implement the principles of *kringlooplandbouw* (circular agriculture) by 2050 to close loops and fertilise the ground naturally by way of a varied planting scheme (Ministerie van LNV, 2019).

After defining the concept of a 'living system' (topic), the next paragraph 'Investigating Existing Research' (literature study) discusses the perspective of the water workers and the need for spatial drawings. The third paragraph 'Towards the Visual Water Biography' (method) explores the theoretical framework of the VWB that builds upon the Dutch layer approach and the landscape biography, adding to them the notion of the cyclical and circular processes. The fourth paragraph introduces 'The *Sprengen* and Brooks system' (study case) to demonstrate the method. Why 'Research Through Drawing' (technique) is so crucial to the development of the novel method is explained in the fifth paragraph. The technique is applied in paragraph six 'Visualising the *Sprengen* and Brooks system' (outcome), supported by drawings that are the main products of the research. Paragraph seven discusses the 'Findings' and is followed by the last paragraph the 'Discussion and Conclusion'.

1 The circular Economy model synthesises several major schools of thought. (Ellen Macarthur Foundation, n.d.) In this research, the two following schools and/or concepts are most relevant: 1) Respect human & natural systems. "Celebrate diversity." This concept is one of the foundations of the 'Cradle to Cradle' school and focuses on the careful management of water use to maximise quality, promote healthy ecosystems, and respect local impacts while guiding operations and stakeholder relationships using social responsibility (McDonough & Braungart, 2002); 2) Ecosystem services theory; In these school ecosystem services are the many and varied benefits to humans gifted by the natural environment and healthy ecosystems. Such ecosystems include, for example, agroecosystems, forest ecosystems, grassland ecosystems, and aquatic ecosystems (Daily, 1997; Brown, Bergstrom, & Loomis, 2007).

Investigation Existing Research

Different publications recognise the necessity to learn from the past and help to find spatial angles to look at living water systems. However, analytical drawings that show the complexity and specificity of human and environmental interaction in living landscapes are mostly absent. In *Europe's Living Landscapes* (Pedroli, 2007) the authors argue that 'no one knows the landscape better than its local communities… even if they lack the scientific knowledge for understanding physical and social phenomena…'. Communities of water workers, who are part of a living water system, are the central figures in *Springs of Life: India's Water Resources.* (Pangare, Pangare, & Das, 2006) The authors document the tangible and intangible aspects of traditional water systems in India to show 'the ways in which communities live and interact with water… and their common-sense solutions to local water problems'. The book also reflects on the importance and crucial role of women as authors (inventors, makers, and managers) of these landscapes and its integrated character. The research of Pangare, Pangare, and Das (2006) and Pangare and Pangare (2016) put great emphasis on the diversity of irrigation and water supply systems and their working principles in relation to the local climate and ecosystems and the interaction with the communities that built and handle them. However richly illustrated with photos they are, their analyses lack the three-dimensional spatial translation and its visualisation. In the recently published book Lo-Tek (Watson, 2019) many beautiful drawings demonstrate people at work creating their landscape by vernacular practices. Drawings, for example, explain the process of the wastewater treatment and its cleaning capacity, but are not related to the specificity of the site, nor to the development over time. In *Stromend Landschap*, a research on the Dutch *vloeiweidenstelsel* (water meadow system), human activities, circular processes of the multifunctional water system, and underlying cyclical processes are revealed as driven forces that continuously shape and change the water system. (Baaijens, Brinkman, Dauvellier, & Van der Molen, 2011) For example, the inundation of fields in wintertime demonstrates how *water farmers* profit from the early growth of the grass, that made it possible to sell primarily healthy, fat lambs to others. In *Landwerk Walcheren* (Loen, De Graaf & Willemsen, 2014), the researchers argue that the 'hands of the *landwerker*' (land worker) have disappeared from the landscape in favour of rationalisation and upscaling, causing a loss of spatial and ecological diversity. By drawing these practices, they illustrate that in order to (re-)develop a diverse cultural landscape, cyclical and circular processes such as daily tidal ranges, yearly seasonal and multi-year cycles of silviculture[2], floating field-, raised bed-, and agroforestry systems must be part of these landscapes. In the Circular Water Stories lab[3] (2018 - ongoing), at the faculty of landscape architecture at TU Delft[4], diverse traditional water systems are mapped and analysed through the lens of circular and cyclical processes to inform and offer insights to the graduation project of the students, in which they design a 'new' water landscape. Students are familiar with the landscape biography approach, which offers a method to question human interaction with the landscape by collecting stories, and integrate this knowledge in the analyses and design part of their thesis. For the analyses of worldwide living water systems, a fixed set of analytical drawings is developed that makes it possible to compare and learn from them[5].

2 Silviculture is the growing and cultivation of trees.

3 The Circular Water Stories lab coordinator Dr. ir. I. Bobbink is part of the Flowscapes studio, the graduation year of the Landscape Architecture master track at TU Delft in the Netherlands.

4 Faculty of Architecture and the Built Environment in the Netherlands.

5 Some work made in the Circular Water Stories lab forms the base of other articles in SPOOL Urban Landscapes #7 and 8 (2020/21).

Towards a Visual Water Biography

"Drawings are to be seen as a means to exteriorize abstract ideas [...] They widen the perceptual span [...] enabling a switch from macro to micro levels, keeping the totality of the concept in mind while dealing with detailed solutions. [...] (Foque, 2010, p. 78)

The VWB focuses on the 'visual' because the analysis of the living water system is communicated through the universal language of drawings. Foque (2010) underpins the importance of the use of drawings in the design process. Moreover, we extend its importance to the analyses of living (water) systems, as one good illustration (map, section, etc.) has the ability to describe complex spatial relationships much more easily and is more accessible than descriptive text. The method is a tool to visualise stories, describing people's actions in relation to the landscape in space and time. The drawings reveal the multifunctional use of water at a specific site concerning the watershed and the ongoing cyclical and circular processes by emphasising the holistic performance of the living water system.

The VWB builds upon the Delft layer approach of analysing landscape compositions and combines it with the method of the landscape biography. A landscape biography emphasises the idea of people being the co-authors of landscapes and puts the focus on an integrative, long-term perspective of landscape changes; it relies on a large and varied set of historical, environmental, and other sources of data to inform studies about the diverse ways in which communities have interacted with their natural and cultural environments through time. (Van den Brink et al., 2017) From a societal perspective, landscape biography[6] aims at a better integration of historical landscape research with urban planning, landscape design, and public participation in local and regional developments. This is something that, according to Kolen, Ronnes, and Hermans (2015), designers and scholars in the field of spatial planning have often failed to recognise, or integrate into their work, a criticism that researchers, educators, and spatial designers acknowledge and which can hopefully be overcome by introducing the approach of the Visual Water Biography.

In the Delft layer method, analytical drawings, rather than descriptions, are used to reveal how the landscape composition is moulded according to the natural layer, the cultural layer, and the urban layer. This layer approach is about research by drawing, as demonstrated by a whole series of publications[7]. Related to the water topic of this article, two titles should be mentioned: the *Polderatlas of the Netherlands*; Pantheon of the Low Lands (Steenbergen et al., 2009) and *Water inSight; an exploration into landscape architectonic transformations of polder water* (Bobbink & Loen, 2013). Particularly in the book *Water inSight* the authors used drawing techniques in which the technical scheme of the water system and the position of the different water elements are drawn in relation to the layers (natural, cultural and urban) in a single drawing. By doing so, one understands its relationship and can point out the specificity of the site and the water system. Moreover, the Delft layer approach understands landscapes as three-dimensional compositions. The analytical drawings do not capture the dynamic interaction between people and the cyclical and circular processes of the environment over time. This gap is bridged by the Visual Water Stories.

6 The word 'biography' relating to the landscape was introduced by the American geographer M. S. Samuels in 1979 in his article 'The Biography of Landscape'. The archaeologists Kopytoff and Appadurai (1990) reintroduced the term in two well-conceived articles 'The social life of things' and 'Cultural biography'. Dutch scientists, T. Spek (2004) and J. Kolen (2005), contributed by PhD research. The biography approach deals with documenting stories of people who are seen as co-authors of the landscape.

7 Published over the last 25 years: Steenbergen C. en Reh, W. (2004). Architecture and Landscape. *The Design Experiment of the Great European Gardens and Landscapes.* Uitgever: Birkhäuser, Basel/Boston/Berlin. Steenbergen, C.M., Meeks, S. and Nijhuis, S. (2008). *Composing Landscapes; Analysis, Typology and Experiments for Design*. Basel, Boston, Berlin, Birkhäuser. Steenbergen C., Zwart van der J. en Grootens J. (2009). *Atlas van de Hollandse Waterlinie*. Uitgeverij 010, Rotterdam. Bobbink, I. (2009). Land inSight, a landscape architectonic investigation of Locus Uitgever: SUN, Amsterdam/Meppel.

The VBM method comprises (at the least) the following analysis drawings:

- Water workers and authorship through linear time (Fig. 8a).
- The multi-dimensional influence of water workers through space and linear time (Fig. 8b).
- Cyclical and circular processes through time space and territorial scales (Fig. 9 & 10).

The order of the drawings is not fixed and goes back and forth, as each thematic drawing reveals more on the workings of the living water systems, and hence feeds the development of the other drawings.

Each drawing is multi-dimensional and should offer the ability to move through scales and time. This can be achieved by making drawings layered, allowing the reader to zoom in and out of different scales and to read the simultaneous interaction between different types of water workers and the living water system. Making drawings available to be viewed on an online platform is helpful. Because an article lacks the dynamic nature of a dynamic platform, 'stills' of multi-dimensional and multi-scale drawings are used.

The Sprengen and Brooks system

As a test-case to demonstrate the Visual Water Biography, the Dutch *Sprengen* and Brooks system, a former living water system, situated at the *Veluwe* is selected. On the flanks of the forest-rich ridges of the *Veluwe*, the largest push moraine complex (1100 square kilometres) in the Netherlands, many *Sprengen* and Brooks systems have been built up and transformed by water workers over the course of several decades, starting in the 15th century (Fig. 1 & 2). The eastern and southern flanks hold 53 of these systems (IJzerman,1981).

In principle, a *Sprengen* and Brooks system is a water-tapping system that diverts groundwater via a network of natural and dug watercourses to power watermills. In short, groundwater is tapped from a hill by digging a hole (*spreng*) in the slope to reach the groundwater table. Because of vertical clay-layers in the soil, this tapping is possible on many sites at the *Veluwe*. The water is then guided via narrow watercourses (natural brooks, transformed or dug canals) in such a way that, for as long as possible, the water is kept on the highest possible altitude, following the contour lines, and then allowed to drop at a place where there is a significant height difference. Here, a watermill that generates energy by the rapid fall of the water stream is situated. Depending on the height of the hill and its geological condition, this mechanism can be repeated along the stream and its branches at different elevations. By managing the water in this way, the development of a new 'light' industry became possible. Similar hydropower water system concepts are established all over the world, for example, in the *Oberharzer Wasserwirtschaft*[8], Germany, the water mills grind the earth into powder for the production of ceramics in Onta, Japan[9] (Wilson, 1995) and the watermills of Sierra de Cadiz in Spain[10] which transformed a whole region into a granary landscape (Rivero, Ramos-Carranza 2020).

8 A UNESCO World Heritage Site since 2010, Oberharzer Wasserwirtschaft is the largest pond and canal system in the world. Since the Middle Ages, it has been the main source of energy for mining in the Upper Harz for more than 800 years.

9 The pottery of Onta made possible by hydropower is labeled as intangible cultural property of Japan. The term refers exclusively to human skills possessed by individuals or groups which are indispensable to produce Cultural Properties.

10 For more information please check the article in this issue of SPOOL #7: The watermills of the Sierra de Cádiz (Spain), a traditional open water re-circulation system.

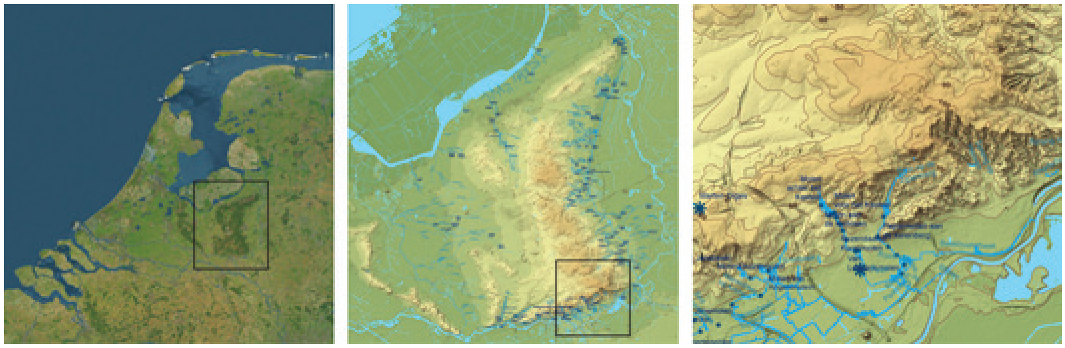


FIGURE 1 The Sprengen and Brooks water system The study area of the Rozendaalse Beek is situated on the south-eastern flank of the Veluwe from where the Sprengen and brooks eventually flow into the river IJssel. Map (a) of the Netherlands, map (b) the Veluwe (brown - height lines and blue - water), map (c) zoom on Rozendaalse Beek by M. Pouderoijen (2019).

FIGURE 2 Historical map of the Sprengen and Brook water system The map depicts the Veluwe area, a push moraine, in a three-dimensional way. The 16th century map, with artistic quality, is engaging and shows the different types of landscapes like forests and heath and the relation between the Sprengen, brooks and the settlements. Source: Wildernis.eu by C. Sgrooten (1570).

The community of water workers who designed and built the *Sprengen* and Brooks system consists of *beekgravers* (brook diggers), *beekruimers* (brook cleaners), millers, craftsmen and -women, farmers, and landowners, sometimes in collaboration, sometimes in competition with each other. A wealth of elements and aspects, like retention basins, dikes, dams, irrigation canals, and controlled floodings were developed to make use of the water in the best way. The water workers developed a silviculture management system with coppicing cycles, to ensure the provision of woody material for the construction and maintenance of the *Sprengen*, brooks, and mill sites. Watermills provided power for the grinding of flour, oil, and copper, and later for the production of paper in the 17th and 18th centuries. After the decline of the local paper industry the mills were transformed into laundry and bleaching mills. Over time the system changed, and due to the availability of other energy sources the mills especially lost their function. A new generation of water workers, drinking water companies, and centralised water boards were unfamiliar with the practices and skills of the traditional water workers. The interference of these companies inflicted damage on the system and the wildlife depending on it.

Research through drawing

When drawing is re-examined in the research context, where it is now being performed as a definitive activity within art and design research, it can be understood in its functionality as a driving force that moves the research inquiry forward. (Mäkelä et al., 2014).

A lot of material relating to the *Sprengen* and Brooks system is collected by the *Bekenstichting*, *Stichting tot Behoud van de Veluwse Sprengen en Beken*[11] (Brooks foundation, foundation to rescue the Veluwse Sprengen and Brooks system) and available in books and on their website. The members of the foundation consist mainly of local people with considerable interest in history, cultivation, geology, ecology, water management, technique, and archology living in the area. The foundation is interested in the preservation of the *Veluwse Sprengen* and Brooks system; it acts as the patron and guard of this unique water system. The foundation manages the online *Bekenatlas* and contributed to the publication *Veluwse beken en sprengen* (Menke, Renes, Smid, & Stork, 2007). Most recently they published the oral history[12] book *Veluwse Waterverhalen* (Water Stories of the Veluwe) with first-person accounts from people who lived and worked, and sometimes still do, within the *Sprengen* and Brooks system (Slijkhuis & Poorthuis, 2019). Paintings and photos are part of their collection. Most stories are not scientific documents but help to understand the relationship between people and water at the *Veluwe*, and bear witness of the integration of different uses of water in a collective, almost public space. Moreover, people in the region were interviewed, and a few field trips delivered site-specific input for the VWB.

Based on this material, analytical drawings of the Visual Water Biography tell the story of the *Sprengen* and Brooks system. The different water workers distilled through research are defined during the time the system arises and develops. Transformations in the landscape can start with the influence of one person or an element making adjustments, which forms the starting point of a chain of developments. Next, the most relevant cyclical and circular processes linked to the condition of certain places on different scales, in which the water workers engage, are identified. The maker of the visual biography needs to decide which cycles, like the day and night rhythm, seasonal cycles, tidal movements and ecological succession[13] are relevant for

11 https://www.sprengenbeken.nl

12 Oral history is a method of historical research. However tainted and/or coloured by personal experiences, the method is especially valuable to give a voice to the marginalised and the 'invisible' such as the poor, women, and/or (ethnic/religious) minorities.

13 Definition of ecological succession: a series of progressive changes in the composition of an ecological community over time.

the specific case. Circularities can be found in different scales as explained in the captions of the drawings. These processes need to be mapped in such a way that it becomes clear how people adapt and make use of them and how these processes shape the landscape. Of course, by making these drawings, one has to bear the amount of information the drawing can carry in mind, in order to stay readable. Analysing is always about being selective.

Three relevant scales - the domain of intervention, the domain of influence, and the domain of effect - according to the territorial approach are defined. (Burns & Kahn, 2005) These domains relate to the intensity of conscious and controlled interference of people in the landscape and are not fixed in a numeric scale but ask for the judgment of the spatial designer. The work to identify these domains is almost inevitable for all spatial analysis. When deciding on the three scales, the units used in hydrology or human geography, such as drainage or catchment area, tributary and sub-stream should be taken into account. Again, there is no fixed step-by-step sequence in this method, the analysis moves back and forth. In that sense, it reflects a design process as described by Elise van Doorn (2013).

Visualising the Sprengen and Brooks System

TIn the case of the *Sprengen* and Brooks system, the domain of effect of actions by water workers concerns the scale of the *Veluwe*. The series of sections, on this scale, show that the water system transformed from a cultivated one to a more utilized one, which today is an urbanised - water system that is kept for its heritage. Timewise, the series overlaps as shown in the diagram (Fig. 10b). The domain of influence is about the scale of 'one' *Sprengen* and Brooks system. As an example, the *Rozendaalse* brook is selected. Of course, each of the 53 systems situated on the east and south flanks of the *Veluwe* can be analysed and documented with the same method, enriching the understanding of the whole *Veluwe* landscape. Other systems might have a smaller pallet of water workers or the same, but due to the different context conditions respond differently and evoke spatial differences in the landscape. The domain of intervention corresponds to the formal (ownership) boundaries of a design site: as put by Burns and Kahn (2005), the location that a designer receives from a client with an associated design question. As we analyse existing situations and do not get involved in the ownership discussion, we define this domain on the scale of spatial ensembles, with different sizes according to the intensity of the cohesion of the elements. For example, a *molenplaats* (mill site) consists of a mill, a pond, dam, tail race, overflow channel, a yard, and trees surrounding the place, and a barn.

Six types of water workers are distinguished (Fig. 8a & 8b), and in different drawings (sections), their specific influence on the landscape is revealed: the role of the water worker as an individual (landscaper, regulator), a collective (utilisers, cultivators, or conservators), a more conscious or unconscious author.
The work of the landscaper as we describe them, a person who creates and makes pleasure grounds and parks, is more locally defined with a clear architectonic expression. The work of the utilisers and cultivators is more stretched in terms of scale and might be less visible for visitors in the area since they are familiar with cultivation of land in general and do not recognise the specific characteristics of the *Veluwe* so easily. Each type of water worker has his/her special relationship with the water system in terms of (multi-)functional usage, cyclical and circular processes. Stories reveal how in the *Sprengen* and Brooks system, and most living water systems, water workers perform multiple roles, changing through the seasons and years as explained below and expressed in the drawings. Specific water workers can be dominant in a particular area at a specific time in history. At other times, the same water workers can be marginal. In the *Sprengen* and Brooks system case we distinguish:

1 Cultivators are water workers related to agriculture or aquaculture: land workers, fishermen, shepherds, woodchoppers. Millers are utilisers but also play their part as woodsmen through the extensive management of woodland groves for the maintenance of the mill and the *Sprengen* and Brook system, while also using their mill pond for fish-farming. Cultivators planted trees around a tap point (*spreng*) to mark it, provide shade, and to stabilise the opening and banks of the brooks. Beech groves provided wood, oil, and fodder for the cattle, which demonstrates aspects of circularity. Local bird- and fish-life profited from the continuous flow of fresh groundwater (Fig. 3).

FIGURE 3 Cultivators: fish farmers Fish farmers at work in 1927. The presence of running fresh water allowed to establish trout cultivation. To stimulate employment during the crisis years of the early 19th century fish ponds and brooks were constructed, some of which are in use up until today. Fish farming took also place in the fish ponds in the parks and grounds of the land lords (landscapers) and in the mill ponds (utililers). Source: Spaarnestad Photo.

2 Utilisers are water workers related to production: stream digger, stream cleaner, millers (corn, oil, paper), laundry, copper production, and drinking water production. How water workers interacted with the cyclical processes, like day and night and seasonal changes, is demonstrated in the case of the millers. Flour millers would collect water in their millponds at weekends. Today's ponds in the forests are therefore relics related to flour milling. Paper- and laundry mills worked continuously throughout the winter, while in drier periods of spring and summer they would have to stow the water in the brooks overnight to use it during the day (Fig. 4).

FIGURE 4 Utilisers: stream diggers Beekgravers (stream diggers) at work in 1927. With their knowledge and experience of the terrain beekgravers were essential water workers who supported the water powered milling industries and shaped the water system. Today the main utilizer within this landscape is the drinking water company. Source: Spaarnestad Photo.

3 Regulators are water workers related to water and land-governing and regulating bodies such as water boards. Historically, regulating agencies were the legal landowners and/or cooperatives of farmers. They ruled in case of water conflicts. The question of ownership (legal, functional, cultural, or spiritual) and the effects of water interests between the different water workers have not been addressed in these

analyses. Nevertheless, stories about these conflicts reveal information about the multiple usages and cyclical processes.

4 Landscapers are water workers and users associated with pleasure gardens: moat digger, fountain maker and maintainer, designer, landowner, and guests. The map (Fig. 5) shows how the landscapers'beautify' a multifunctional landscape. The ponds of Castle Rozendaal were huge fishing ponds where large quantities of water could be stowed to irrigate the pleasure gardens as well as guaranteeing water supply for their own mills.

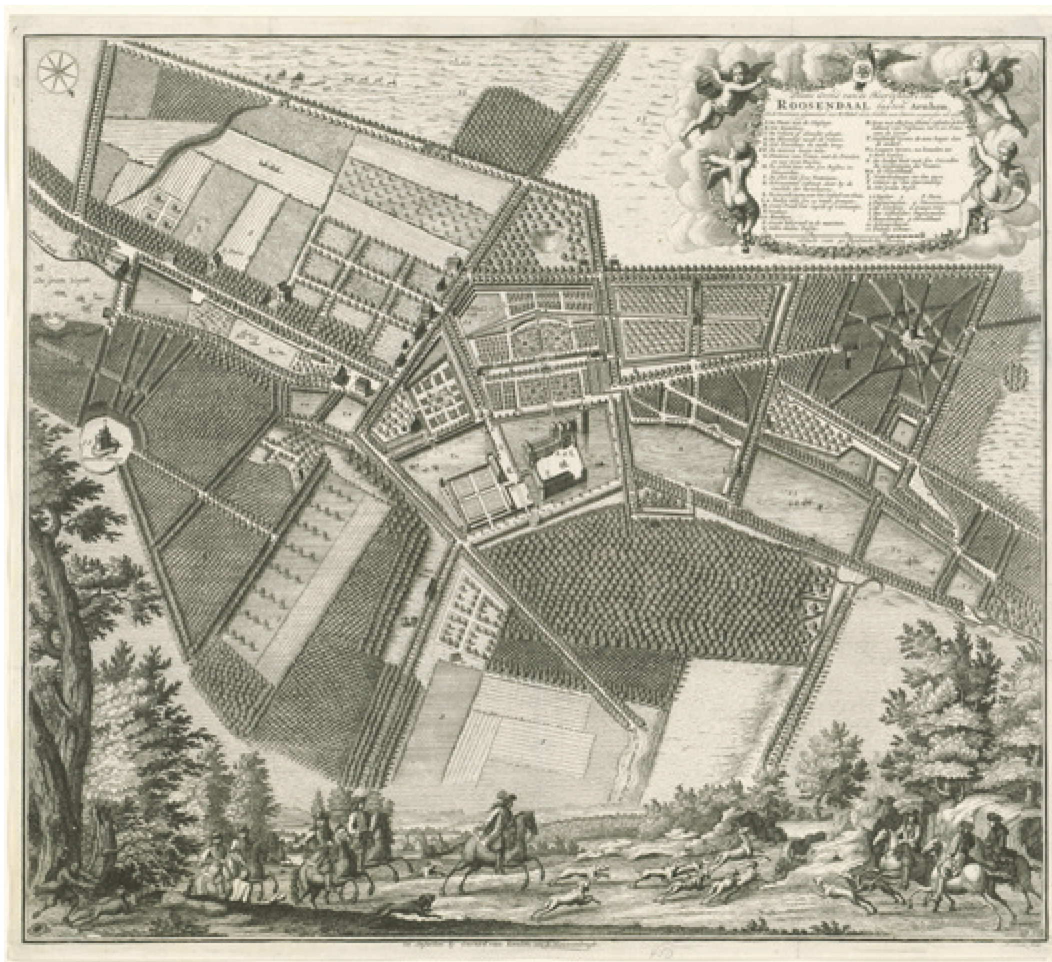


FIGURE 5 Landscapers: landlords The historical map of the gardens and grounds of Kasteel Rosendael, as created by Janne Magriete & Jan van Arnhem gives insight in the many ways the landscapers beautified the landscape while also engaging in and allowing for the activities of utilisers and cultivators. The drawing explains, with both, artistic quality as well as technical accuracy the function of the water works, such as fountains for the pleasure gardens, the irrigation system for the kitchen garden and the channels digged to bring the water to the mills. *Platte grond van de heerlykheyt van Roosendaal buyten Arnhem* (Dutch titel of the object) By: Jan Smit, Berend Elshof and Gerard van Keulen. Date: 1718. Source: Rijksmuseum.

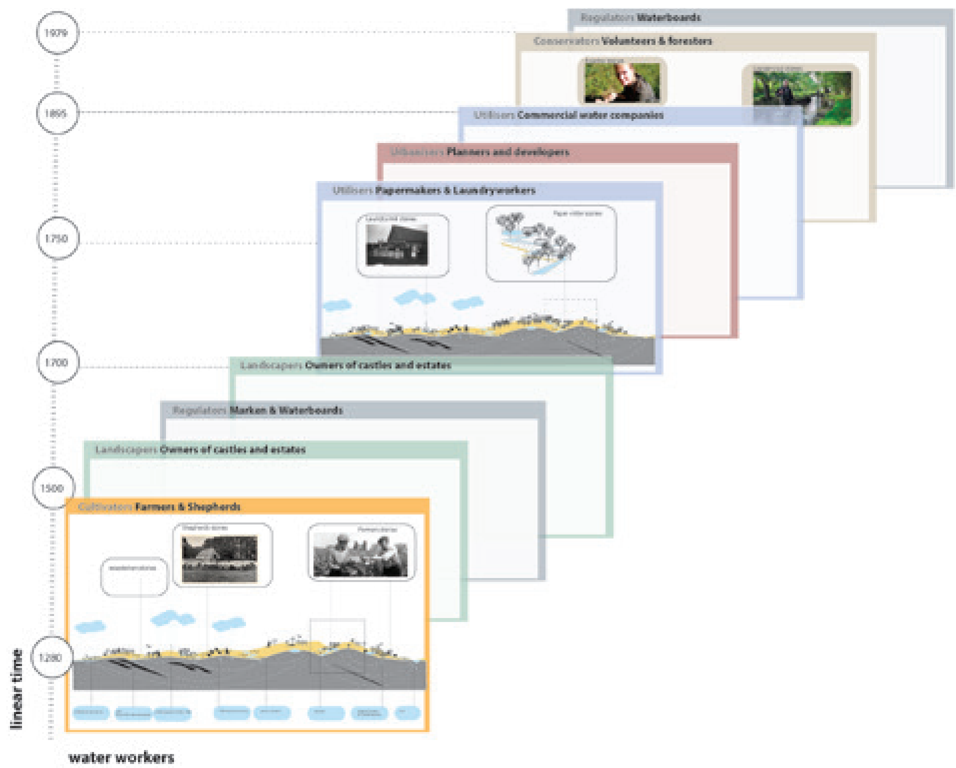
5 Urbanisers are water workers and users associated with the urban area: public space designer, swimmer, citizen, and stroller. Urbanisers transformed the living water system into a more passive system for the beautification of the residential area, while at the same time ignoring and interrupting the system to make a place for urban development (Fig.6).

FIGURE 6 Urbanisers: users
The postcard (ca. 1920) depicts a picknick in the park of Kasteel Rosendael. When the towns and villages around the estate expanded the grounds and the surrounding cultural landscape became an important backdrop for leisure and recreation. Today recreation and tourism are an important pillar of the local economy.
Source: Collection T. Nelemans / www.mijngelderland.nl.

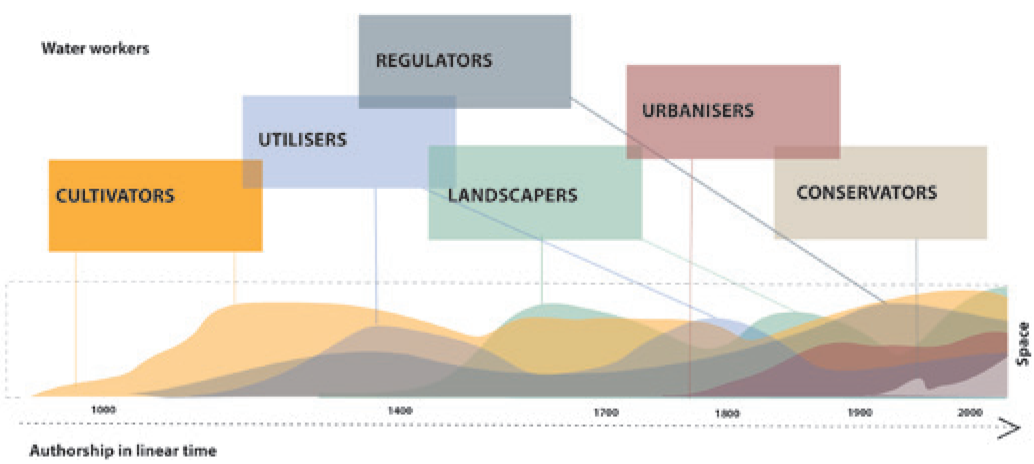
FIGURE 7 Conservators: citizen groups
Conservators at work in the early 1980's restoring the Sprengen and Brooks system while a jogger passes by. The conservators, a citizen's organization collaborating with the Bekenstichting, made a profound impact of this neglected water living system by advocating and collaborating with the regulators (water boards and local governments) to preserve and manage the system in an appropriate manner and to increase knowledge on this historical water- and ecosystem.
Source: Photo collection Bekenstichting.

6 Conservators[14] are water workers and users related to heritage and nature preservation: members of the *Sprengen- en Bekenstichting*, *Natuurmonumenten*, nature lovers (citizen). The *Sprengen* and Brooks system is no longer used and managed by the traditional water workers since the decline of the paper and laundry industry, and has lost its economic benefit. When the traditional water workers' (who designed, built, and managed it) involvement in the living water system with its distinctive flora and fauna declined, it slowly fell into a state of disrepair and overgrowth. Only relics of the system remained. Nevertheless, local people discovered the system because of its historical significance, its cultural and ecological specificity, and were inspired by stories from the past, leading them to advocate for its conservation. Alarmed by the mismanagement and the lack of knowledge within local governments and water boards, illustrated by the way clay layers from brook beds were demolished, they started building up conservation networks and a body of knowledge (Fig. 7).

14 The nature and heritage conservation movement came to light at around the industrial revolution as bottom up movements by local individuals and groups and public figures started to oppose the bringing into culture of primal nature areas such as woodlands and marshes. This eventually stimulated the development of institutional nature and heritage organisations and policies while NGO and local activists still play an important role in the discourse around nature and heritage conservation. (Van der Meulen, 2009)



a



b

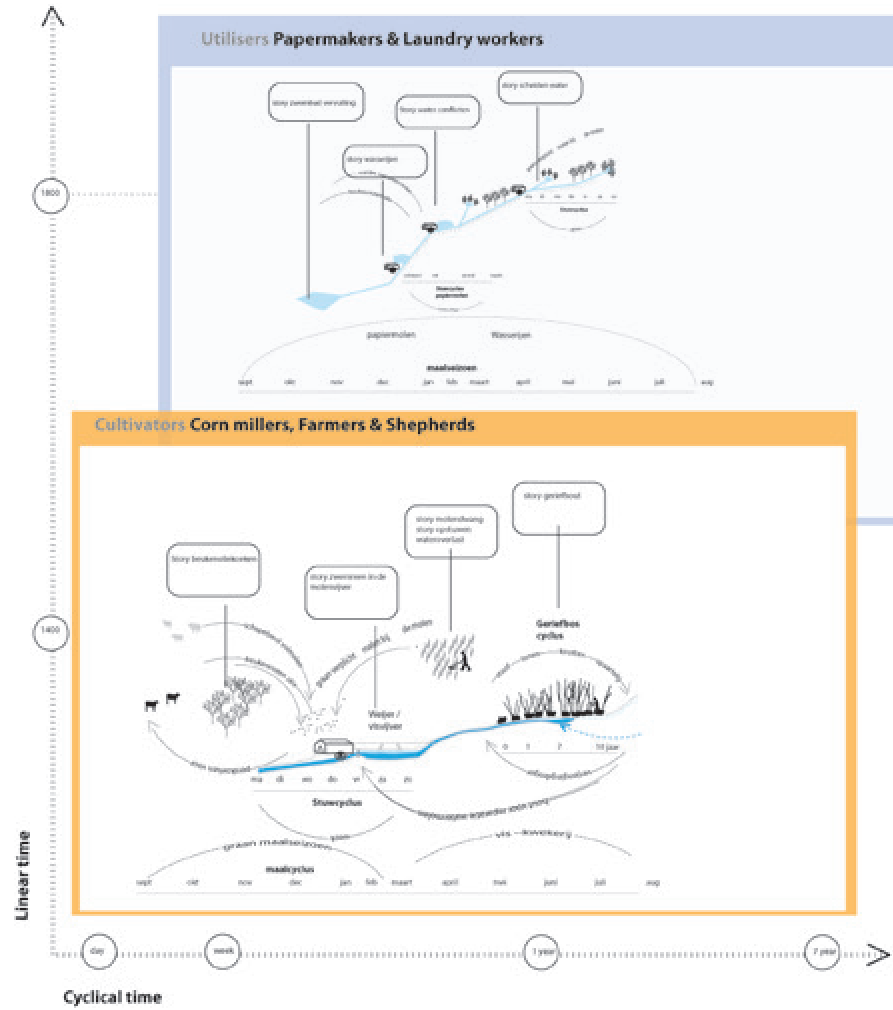
FIGURE 8

a. Water workers and authorship in the Sprengen and Brooks water system.

With this diagram we explore how to communicate and visualise the engagement of water workers and their specific spatial impact through time. This diagram shows the multi-layered usage and transformation of the landscape and the water living system. The drawings are abstract and at the same time site specific and describe the dynamic of the landscape. It becomes, for instance, apparent that utilisers are still dominant in the landscape. In the 18th century the utilisers left their marks as paper makers, today the water companies leave their mark on the system by restraining groundwater.

b. Water workers and authorship through linear time.

This diagram is a tool to gain insights on the impact and dominance of diverse authors on the landscape through time. The diagram identifies and communicates by analysing space and stories different categories of water workers, who have left their mark (or continue to do so) on the landscape by creating a water living system through time. It shows the complexity through time as more different categories of water workers engage in the cultivation and exploitation of the landscape. Note that the dominance of a category or certain type of water worker in a water living system may vary through time, or disappears altogether.



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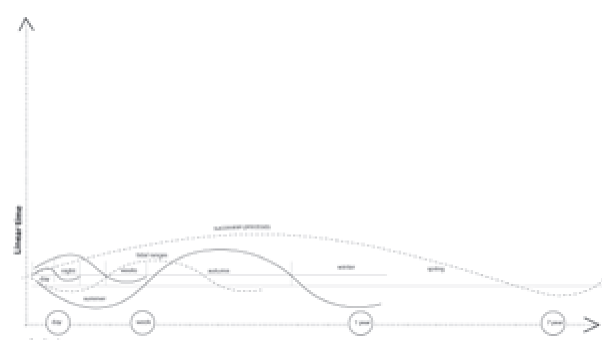


b

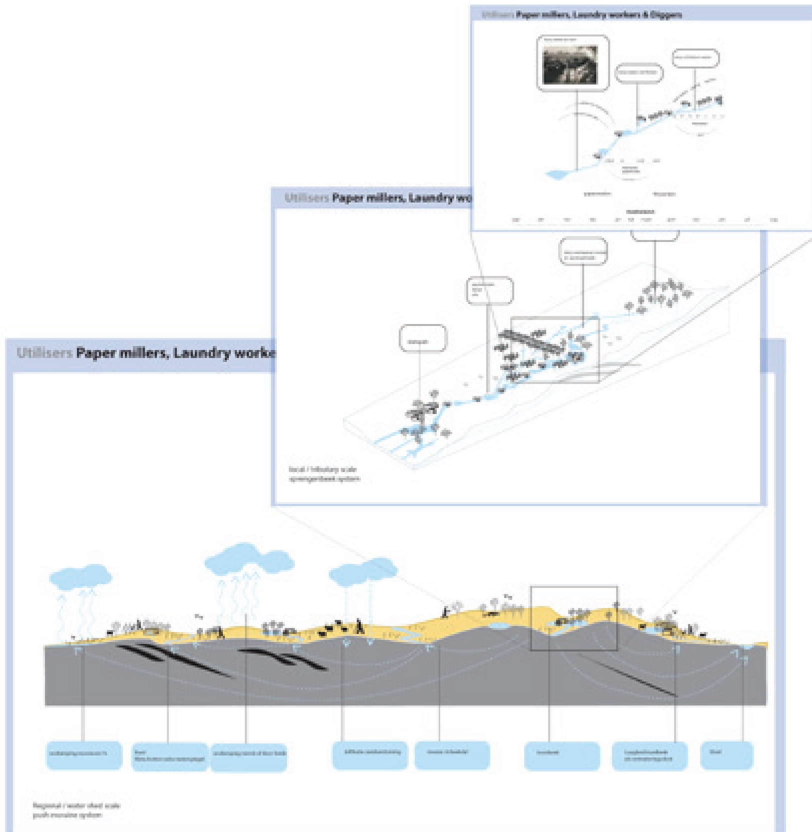
FIGURE 9

a. Cyclical and Circular processes in the Sprengen and Brooks water system.

This diagram reveals how different types of water workers in the case area, even within the same category and/or simultaneously, may live and work with different cyclical processes and time scales. For instance, paper makers needed a continuous flow of water for their mills, while corn millers collected water in the milling ponds at weekends, resulting in conflicts with farmers who wanted to flood their fields. Diagrams by S. Loen / LILA landscape (2020).

b. Cyclical and Circular processes.

This diagram is a tool to identify, by analysing space and stories, the cyclical processes, like seasonal cycles and tidal ranges, which occur in a water living system and shows how water workers make use of, adapt to, or develop their life according to it.



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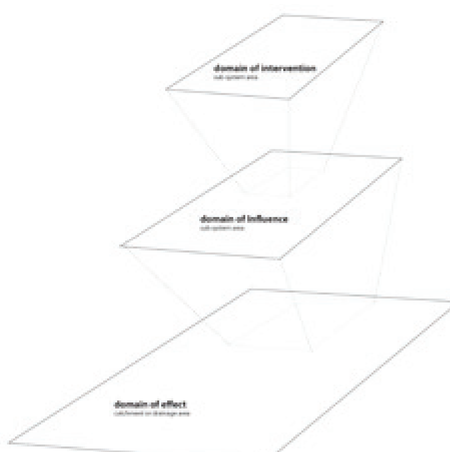

b

FIGURE 10

a. Range of territorial scales in the Sprengen and Brooks water system.

The diagram of study area Rozendaalse Beek in the Sprengen and Brooks system shows the three selected domains or territorial scales related to the utilisers, and more specific of the paper millers.

b. Range of territorial scales.

This diagram is a tool to identify by analysing space and stories the relevant spatial scales in a water living system. These scales are, as explained in the method paragraph not fixed or premeditated. The scales, or rather domains, are related to the category of water workers within the water living system.

Findings

The analyses of the VWB approach provide insights in a more societally integrated, site-specific, and adaptive water management approach. It offers an analytical tool to visualise the complex interaction between people and water through time and space, systematically and engagingly (living water system). By using the method, spatial planners, researchers, and designers can identify and understand these systems and their value, for the betterment of society.

Defining the categories of water workers seems easy but is, in fact, subject to great discussion. The visualisation of groups of water workers and the acknowledgement that these groups are fluent and layered is, however, a fundamental notion. The categories of water workers are a tool to understand the interaction between people and space in time, but should not be a restrictive framework. Other authors can be considered, depending on the goal of the research.

The topics of cyclical and circular processes are concepts that are often overlooked in spatial analyses and planning, with the exception of flood-proof design. Stories of authors and users reveal a wealth of cyclical and circular principles that could not be exposed and understood in its complexity through spatial analyses alone. Living landscapes are based on the notion of using and caring for the elements the landscape has to offer.

Living water systems deal with the tension between the social, legal, and geographical definition of space and ownership. Each living water system will have its own specific features in this regard.

It is important to stress that the analysis of the living water system is not steeped in a motivation to idealise or romanticise the systems and the way communities live (or have lived). It is merely a method to gain knowledge and inspire future water workers to think more holistically.

Discussion and Conclusion

The development of the VWB analyses method is an ongoing 'research through drawing' process. The presented drawings in this article are a selection of the many that were made for this study. We needed to experiment on how we could draw the main topics of the visual water biography in the best way. This whole process could be elaborated in another article, which might discuss the choices one has to make in analytical drawings that reveal live circumstance and its influence on the landscape.

Such research into the past need's further elaboration, since the landscape, as well as the climate, must have changed over this long time period. Change in the brook flow, flood frequency, rainfall distribution, and agricultural practices are among the factors that have changed the system over the past centuries and are not yet illustrated in the presented drawings.

Besides, there are more stories, for example, about flora and fauna, sounds and smells of specific locations passed on through generations that are interesting to present. In addition, precise maps in this article are unleashed since we decided to focus on a higher level of abstraction to illustrate the method of the Visual Water Biography.

In this phase of the research, we focused on the interaction between humans and their surroundings from a 'functional' perspective related to cyclical and circular processes. However, we expect that the VWB method could help to reveal the influence of spiritual or ideological beliefs on the interaction between humans and their surroundings, as well as reveal conflicts in the system between legal, functional, cultural, and spiritual ownership in (living) water (systems).

A digital version of the VWB, open for continuous additions, able to include the vast material of the landscape biography, needs a lot of extra work and requires a lot of testing but ultimately seems to be the most appropriate way to show the complexity and richness of these living water systems.

The Visual Water Biography method needs more testing on other cases, different types of living systems and scales and should develop further according to the comments of the professionals. We use it already in education to teach landscape architectural students to be more aware that landscape needs to be approached holistically; a design is a process needing to be 'carried' by people and needs constant adaptation.

The method offers an approach in which complex relations between people, landscape form, water dynamics, water use, water meaning, water adaptation, technical development, related programme, and ecosystems can be illustrated and explained comprehensively. By understanding the role of people and the concept of cyclical and circular processes, designers can act accordingly. The method, therefore, can be used for other living landscapes with a focus other than water.

To conclude, the Visual Water Biography method illustrates that taking workers as the starting perspective of landscape analyses helps to reveal aspects of human and environment interactions that are generally overlooked or misunderstood. The research of the VWB underlines that, as the interest in human and intangible aspects of landscape grows, researchers and practitioners in the field of landscape architecture do not need to do the work of historians or anthropologists themselves. It instead asks for a different way of 'reading' the available oral and other historical 'material' and is an incentive for interdisciplinary collaboration; through collaboration it is more likely that we can understand and are able to develop resilient living water systems for the future.

Acknowledgements

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References

Bobbink, I. & Loen, S. (2016). The water-rich landscape: from a reclaimed landscape to an enjoyable landscape. In: Heuvel, M., van den (Ed.) Blue Bliss, the art of enjoying water. Zwolle: WBOOKS.

Bobbink, I. & Loen, S. (2013). *Water inSight, an exploration into landscape architectonic transformations of polder water.* Retrieved from http://repository.tudelft.nl

Brink, van den A., Bruns, D., Tobi, H., & Bell, S. (2017). *Research in Landscape Architecture: Methods and Methodology*. p.17. New York: Routledge.

Burns, C. & Kahn, A. (2005). *Site matters: Design concepts, histories, and strategies.* New York: Routledge.

Foque, R. (2010). *Building Knowledge in Architecture.* Brussels, Belgium: University Press Antwerp

Ellen MacArthur Foundation. (n.d.). *Circular Economy.* Retrieved from https://www.ellenmacarthurfoundation.org/circular-economy/concept.

Hein, C., van Schaik, H., Six, D., Mager, T., Kolen, J. J., Ertsen, M., ... & Verschuure-Stuip, G. (2020). Introduction: Connecting Water and Heritage for the Future. In C. Hein (Ed.), *Adaptive Strategies for Water Heritage.* pp. 1-18. Cham, Switzerland: Springer Open.

Kolen, J. C. A. (2005). *De biografie van het landschap. Drie essays over landschap, erfgoed en geschiedenis. [The biography of the landscape, Three essays on landscape, heritage and history.]* Vrije Universiteit: Amsterdam.

Loen, S. (2019). Thirsty Cities: Learning from Dutch Water Supply Heritage. In C. Hein (Ed.), *Adaptive Strategies for Water Heritage.* pp. 79-105. Cham, Switzerland: Springer Open.

Mäkelä M.A., Nimkulrat N., & Heikkinen T. (2014). Drawing as a research tool: Making and understanding in art and design. Studies in Material Thinking, Retrieved from www.materialthinking.org. Vol. 10 *The Art of Research,* ISSN 1177-6234, AUT University.

Pangare, V. & Pangare, G., (2015). Ancient Water Wisdom: Traditional water systems India. In Willem J.H. Willems & Henk P.J. van Schaik (Eds.), *Water & Heritage: material, conceptual and spiritual connections*, pp. 57-69. Leiden, Netherlands: Sidestone Press.

Pangare, V., Pangare, G., & Das, B. (2006). *Springs of Life: India's Water Resources.* New Dehli, India: Academic Foundation.

Renes H., & Samuels, M. S. (1979). The Biography of Landscape. Cause and culpability. In D.W. Meinig (Ed.), *The interpretation of ordinary landscapes. Geographical essays*. New York, Oxford: University Press.

Pedroli, G. B. (2007). *Europe's living landscapes: Essays exploring our identity in the countryside.* Zeist: KNNV Publ.

Spek, T. (2004). *Het Drentse esdorpenlandschap: Een historisch-geografische studie. [The esdorpen landscape of Drenthe: a historical-geographical study.]* Utrecht: Uitgeverij Matrijs.

Steenbergen, C.M., Meeks, S., & Nijhuis, S. (2008). *Composing Landscapes; Analysis, Typology and Experiments for Design.* Basel, Boston, Berlin: Birkhäuser.

Steenbergen, C.M. & Reh, W. (2003). *Architecture and Landscape; the Design Experiment of the Great European Gardens and Landscapes.* Basel, Boston, Berlin: Birkhauser.

Steenbergen C.M., Reh W., Nijhuis S., & Pouderoijen M. (2009). *Polderatlas of the Netherlands. Pantheon of the Low Lands.* Uitgeverij THOTH, Bussum.

Slijkhuis, H. & Poorthuis M. *Veluwse Waterverhalen, de economische kracht van Sprengen en Beken.* Enschede: Stichting tot behoud van de Veluwse Sprengen en Beken.

Stowa (2018). *Handboek Beken en Erfgoed. [Handbook Brooks and Heritage.]* Amersfoort: STOWA & RCE.

IJzerman, A.J. (1981). *De Srengen en Sprengbeken van de Veluwe, Ontstaan beheer en watervoorziening [The springs and springbrooks of the Veluwe, Origins, management and water supply.]* Wetenschappelijke mededelingen K.N.N.V.

Watson, J. (2019). Lo-TEK, *Design by Radical Indigenism.* pp. 328 and 335. Cologne: TASCHEN.

Wilson, R. L. (2005). *Inside Japanese ceramics: A primer of materials, techniques, and traditions.* New York: Weatherhill.

A Study on Traditional Asian Gardens as Parts of Water Network

Hybrid System with Ornamental Garden Ponds and Functional Water System in Historical Cities in Japan

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Abstract

This research is aimed to reveal how to work hybrid system with ornamental garden ponds and functional water system in historical Japanese gardens cities through researching old maps, documents and measuring canals and garden ponds in three historical cities (Edo/Tokyo, Kanra-Gunma, Kojirokuji-Nagasaki). As a result, the following things are revealed. (1) If over 50% of canals runs through private land, canals are divided complicatedly to reducing risk to stop and pollute. (2) Lord of these cities lived in end of the system to check whether water quality of whole water network is good or not. (3) In most of cases, canal are not directly connected to garden ponds. In only cases which garden ponds have function to control amount of water in downstream or upper stream, garden ponds are directly connected.(4) Garden design variety get rich with topographical situation.(5) In gardens, canals are divied to different use; ornamental use and functional use for daily life.

Keywords

landscape architecture, traditional garden, water network, historical aqueduct, green infrastructure, Japanese gardens, garden design

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Introduction

This paper aims to understand the cultural landscape of water infrastructure to discover a new principle for sus-tainable green infrastructures. Today, green infrastructure is more important for cities considering the current ab-normal climate and global warming. It is essential to discuss how to solve and live together with likely future natural disasters. In particular in Japan, with the experience of deca-centennial Tsunamis with earthquakes, such as that of 11th of March, 2011, there is the realisation that it is impossible to protect cities from disasters completely. From different points of view, for the past 50 years or so, Japan's infrastructures have been constructed in such a way that they can be mended or replaced due to aging and overestimated lifespan. However, under sluggish economic growth, and consequently lower budgets, it is impossible to maintain the same quality of infrastructures by repairing and reconstructing. Under these situations, we need to replace some infrastructures to new principles of infra-structures to sustain with a low cost such as green infrastructures. The comprehension of historical green infra-structures gives hints that may provide an answer to this difficult challenge.

Asian countries have many gardens constructed in cities. Some gardens are connected with a view, water, and life cycle. Kyoto in Japan and Suzhou in China are very famous garden cities. However, most research focuses on the specific gardens in terms of their histories, spaces, stories, and decorations, while few comment on the relationship between gardens and cities. So, this research focuses on gardens as a cultural landscape with water networks, starting with a very simple question: "What is the role of gardens in the water network?".

Visible connections between gardens and cities are famous techniques; the concept of "borrowing scen-ery" in Asian gardens is a familiar topic for researchers. Yamaguchi, Nakashima, and Kawasaki (2009) reveal a visi-ble area from each famous garden as borrowing scenery in Kyoto, Japan, and also points out the relationship be-tween garden design and "borrowing scenery" by view-shed analyses of GIS. The relationship between garden de-sign and topography is clearly described with three-dimensional diagrams of European gardens by Steenbergen and Reh (2003). Their research has productive suggestions for garden preservation by combining three-dimensional spa-tial data with internal and external gardens. This paper addresses the combination of the garden plan with sur-rounding geographical information to analyse the relationship between gardens and cities with water networks.

A water connection is an essential component in the analysis of the relationship between gardens and ur-ban structures for the Asian gardens because garden ponds are one of the main structures in Asian gardens (Inatsugi, 1990). Even in enclosed gardens, garden ponds must be spatially connected to the water network. In cit-ies, the use of water networks connected to gardens for specific functions such as drinking water supply, daily life use, and factory use need appropriate planning and design. This research reveals actual connections between wa-ter networks and garden ponds. Since ancient times, Japanese gardeners have paid special attention to water sup-ply. Mori (1962) pointed out that in ancient Kyoto, the imperial city "Heiankyo", in the 8th century, garden placement was influenced by topography and water resources. After the Edo period (1603 - 1868), many garden cities with water networks were constructed. One of famous examples is Matsushiro, Nagano, for which Sasaki and Nagai (2016) have revealed the entire network and design of garden ponds in the city. In the Meiji period (1868-1912), the industrial canal from Biwa lake to Kyoto was used for the water network of gardens in Higashiyama, Kyoto, devel-oped as villa and temple gardens. Amasaki (1984) reveals the whole network and system. The survey by Sosuke and Morimoto (2003) of Kyoto's water system shows incredible facts about the water network in Higashiyama, Kyoto. Their biological survey reveals garden ponds that are connected to the water network have preserved distinct fish species in Biwa lake (the original water source of the water network). It means that garden ponds with water networks can be refuges and sanctuaries for flora and fauna as a hybrid cultural green infrastructure. These authors develop an understanding of whole images of gardens in water networks in Japan. However, it is not clear what the relationship between garden design and water network systems specifically is. The objective of this paper is to understand how to realise ornamental gardens and practical water systems in the same network as multifunctional traditional green infrastructures.

Water network

Garden Design

FIGURE 1 Digitalized map for the analysis.

Digitalised old maps and measuring gardens and canals

The research method is based in mapping. The historical map of Edo from the early Meiji period is used to read water networks or garden design. However, these maps are distorted because of inaccurate measuring techniques, so adjustment or modification to digital data is necessary to be able to analyse with GIS. The first step is to cali-brate old maps and old drawings of gardens to understand the original situation of gardens and water networks that were demolished or modified. In some of these maps, design details are missing, a deficiency that is solved by field surveys and measuring with a laser measuring system (Fig.1). Both water network maps and garden plan drawings are connected with one digitalised map used to analyse their relationship. In some cases, stakeholders were interviewed to understand how the network worked previously.

In this research, cities to analyse were selected using the following criteria:

- Several garden ponds exist/existed in one city.
- Historical maps or drawings to describe both water networks and gardens were in existence.

WATER NETWORKS WITH GARDENS, EDO, KOJIRO-KUJI, KANRA.

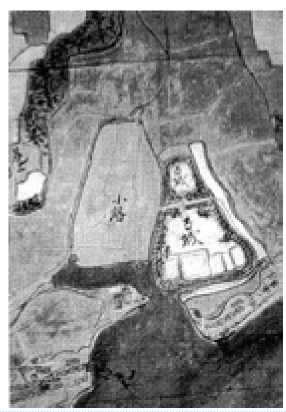
City	Edo	Kojiro-Kuji	Kanra
Description	Water Resource: river, sea water, spring water, canals Over 1,000 gardens are constructed in the city Rich topographical situation from sea to plateau Rich historical documents Most of Garden style in Edo are circuit garden style, which distinct Japanese garden style in history Remain first measured map of Tokyo published in 1883-1884,scaled 1 to 5,000 which is clear to read design of gardens	Water resource: river 11 gardens remain Remain both water system and garden ponds Canals flow through one garden to another garden (not flow in public area) House of principal of the village is located downstream of the network	Water resource: canal Over 10 gardens remain Remain both water system and garden ponds Hybrid system with garden ponds and drinking water system Three branches from main canals flow south to north on the plateau with gentle slope Rich documents about gardens and water system in Edo Rich historical documents Remain illustrated map published in Edo period which is clear to read water network
Period	Edo	Edo	Edo
Topography	Plateau-Lowland	Lowland	Plateau
Water network	Natural resource: river, sea, spring water Canal: Drinking water, Irrigation water, Daily use	Natural resource: river, sea Canal: Daily use	Natural resource: river Canal: Daily use, Irrigation
Garden type	Circuit garden Garden for view from house	Garden for view from house	Circuit garden Garden for view from house
Owners of gardens	Buddism monk Warrior / Lord	Warrior	Warrior / Lord
Historical map			
Map	First measured map scale 1:5000 in early meiji era (五千分一東京図測量原図)	Map drawing of Kojiro village in Edo (神代村図)	Map of Obata area in Edo (小幡藩陣屋内絵図)
Water network	Unclear	Clear	Clear
Garden design	Clear	Unclear	Unclear
Remain water network	Not remain	Almost remain	Not remain
Remain garden ponds	Few garden ponds	Almost remain	Almost remain
Analysis	*Analysis based only on the old map*	*Analysis based on the map and field survey with measuring*	*Analysis based on the map and field survey with measuring*

TABLE 1 Water networks with gardens, Edo, Kojiro-kuji, Kanra.

Finally, three sites, Edo (old name of Tokyo), Obata, and Kojirokuji, were selected to research, as they are all garden cities constructed around the Edo period, with existing old maps from which to read the original situation of the water networks. The relationship between big cities and gardens can be understood through the topography between the plateau and the lowland through the city analysis of Edo. However, most gardens and water networks were demolished and changed. Obata and Kojirokuji, which remain both water networks and gardens, are the best examples of such analysis. Obata is located on a plateau with the canal for daily use and irrigation. Kojirokuji is located in a lowland near the sea with the canal accessible for daily use (Table 1).

Garden ponds as water reservoirs

The results of the analysis of the three cities' water networks with garden ponds show that garden ponds have a function as water reservoirs for the water network. The water network in Edo (historical name of Tokyo), which has over 1,000 garden ponds, shows many examples of how garden ponds are connected to water networks. Edo, placed between the plateau and the lowland, has many small rivers that flow from the plateau's edge and also fac-es the sea (Edo bay). These water resources are used for garden ponds. The first measured map from 1883 shows this clearly, and over 1,454 garden ponds are revealed from the map (today, only 18 gardens are preserved as offi-cial heritage). These garden ponds resulted from city expansion after the big fire in 1657. Edo city was located in the only seafront area in the lowlands before the fire, and there were fewer than 277 garden ponds. After the fire, the government forced its citizens to move outside of the Edo area, which has good topography and water re-sources from the edge of the plateau and seawater. Analyses of Edo's first maps show that garden ponds quadru-pled in number and increased by 150 % in area after the fire. So, the city expansion that resulted from the recovery from the fire diversified the water resources and garden designs (Fig. 2). Through analyses of Edo's first measured map, it reveals that different connection types depended on the location upstream or downstream in rivers. Most of the gardens upstream had spring water points inside the gardens and directly connected to garden ponds with dykes as small dams. These gardens are located alongside the edges of the plateau from which water springs; this controls an amount of water downstream. A similar structure is found in the imperial garden "Shugakuin Rikyu" in Kyoto, where a dyke was constructed to store water for rice fields in the garden area. Most gardens downstream or at the seafront have one water connection - ditch to rivers - to pull water into garden ponds. Water is controlled with gates to intake and drain. The gate can be seen between the garden and the sea in the garden "Hamarikyu". These examples upstream and downstream show that garden ponds are not connected directly to main streams, but placed as water reservoirs of the water network, which allow for the adjustment of the amount of water (Fig. 3 and Fig. 4).

The water network in Obata, Kanra, Gunma, has eleven garden ponds and shows the combined system for daily uses and garden uses. Obata, placed on the plateau alongside the river (Ogawa), has many small canals that run from the main canal (Ogawazeki) to the rice fields area. Each house has at least one garden pond, which is used not only for garden uses but also for daily life as a water reservoir. Eight gardens in Obata have deeper ponds which have rectangular shapes that are most useful for daily life.

The water network in Kojirokuji, Nagasaki, in which eleven garden ponds remain, shows the combined system for dykes for flooding and garden uses. Kojirokuji, located on the lowlands alongside the river (Minotsuru river) and facing the sea (Ariakekai), has four main canals with garden ponds. Each house has a series of piled stone walls alongside the main canal to prevent flood water from the river reaching the houses. Garden ponds are also used for daily life and are strategically placed behind the stone walls to provide continuous access even during times when the river floods.

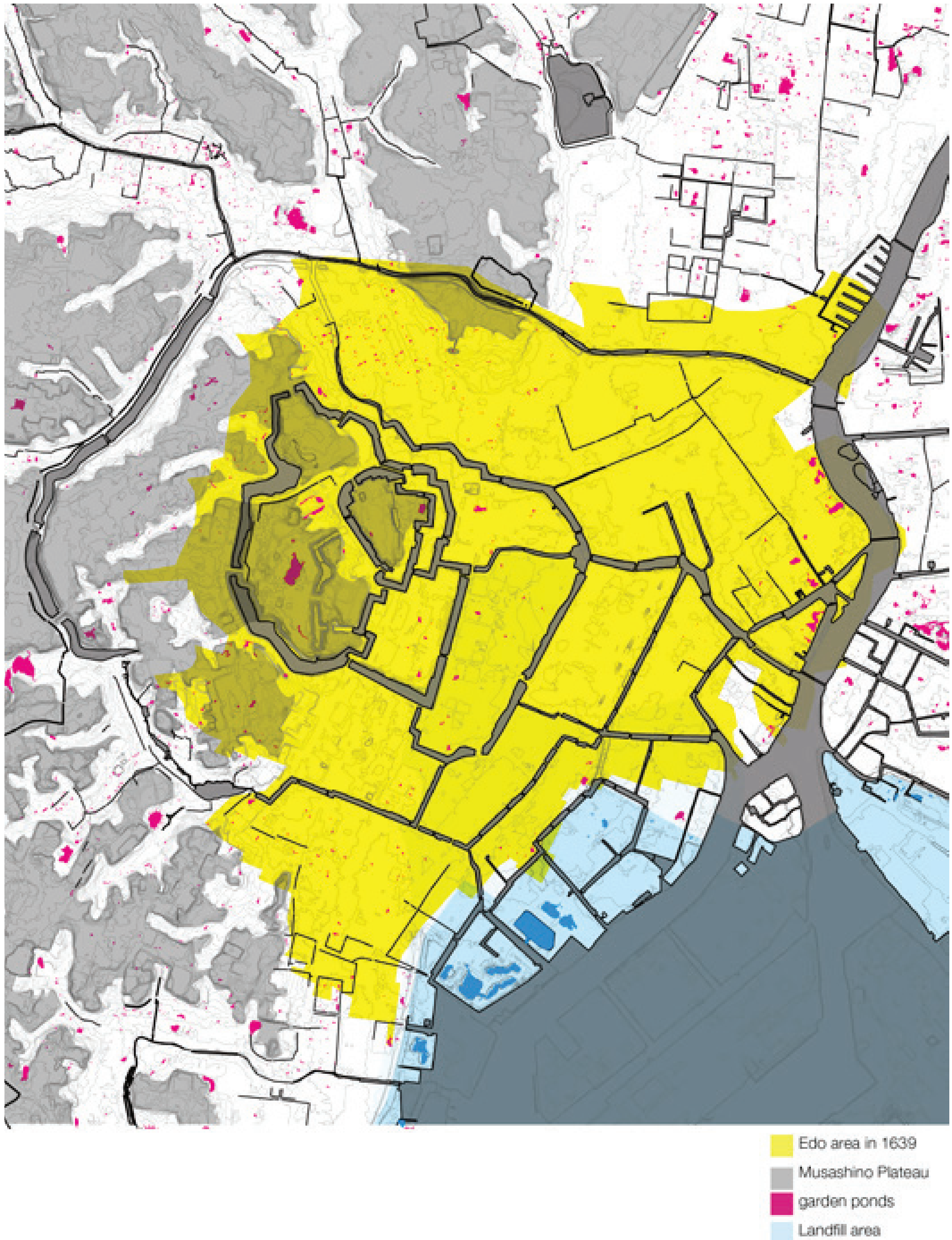
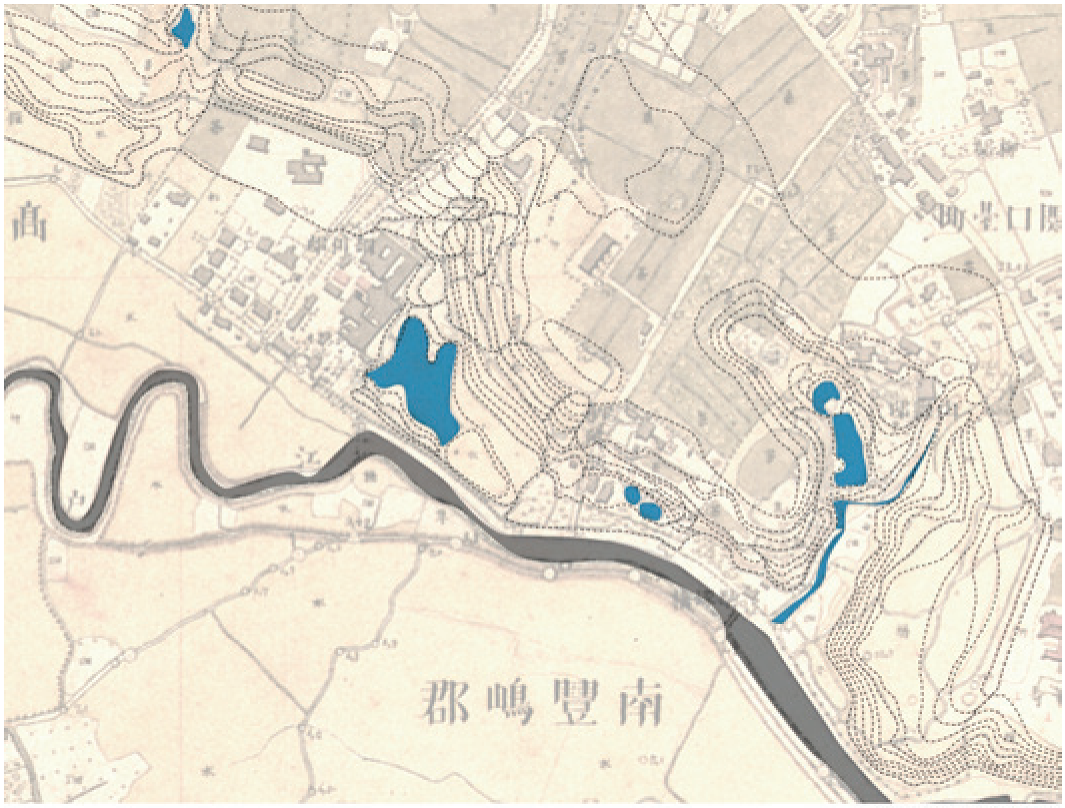


FIGURE 2 Garden ponds and city expansion in Edo.



*based on map in 1883

FIGURE 3 Garden ponds in upper stream and topography *based on map in 1883.

Main river

Garden ponds

- - Contour line

*based on map in 1883

FIGURE 4 Garden ponds in down stream *based on map in 1883.

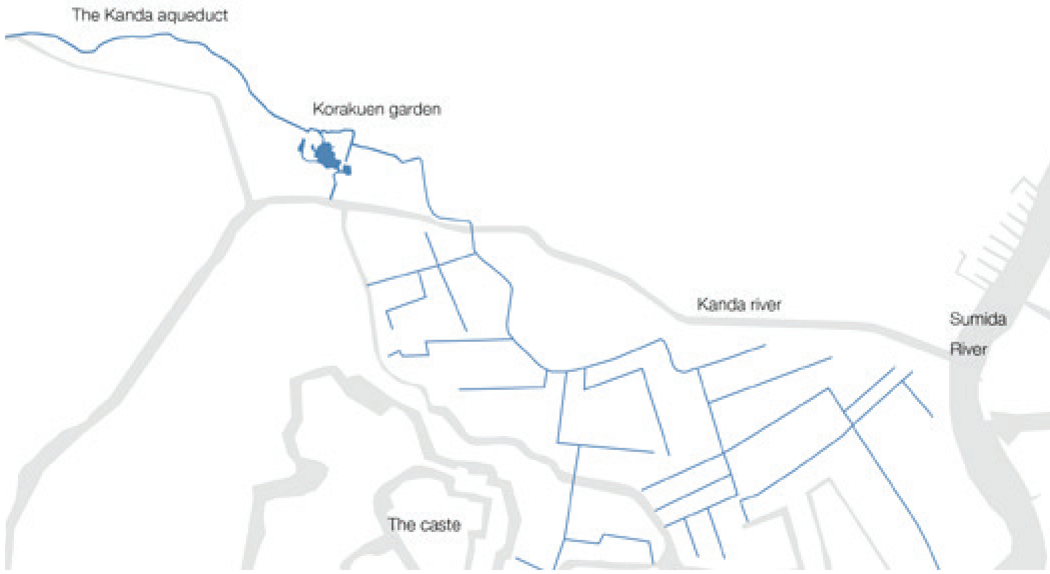


FIGURE 5 Korakuen garden as parts of the aqueduct network in Edo.

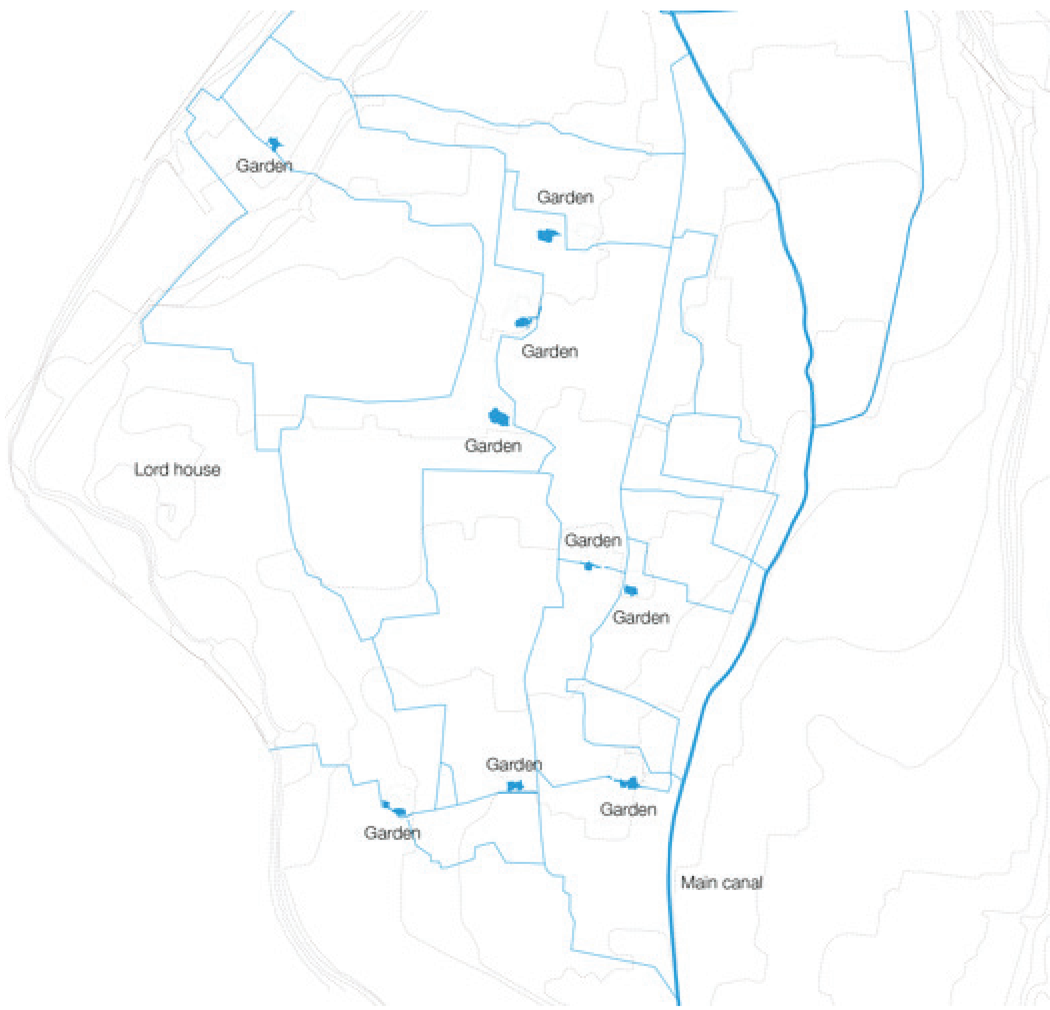


FIGURE 6 Water network and garden ponds in Obata, Kanra, Gunma, Japan.

Connection between garden ponds and water networks

In most cases, in the three cities, the garden ponds are connected to water networks with diversions; the garden ponds are placed in branches that are separated from the main streams to remove risks to the main functionality of the canals.

Six aqueduct canals for drinking water and irrigation in Edo (Kanda, Tamagawa, Aoyama, Mita, Senkawa and Honjo) also connected to garden ponds with diversions.However, kanda aqueduct canal in Edo directly con-nected to lord's family (Tokugawa family in Mito 水戸徳川家上屋敷) gardens, "Korakuen(後楽園)", and the garden controlled an amount of water as the inlet point from Kanda river and adjusted the appropriate amount of water to meet the demand of the entire water network. However, by reconstructing the gardens, the garden ponds have be-come a part of the branch that is divided from the main streams. Other gardens ponds in other aqueducts (ex: Nai-to family in Takato 高遠藩内藤家下屋敷) also have similar functions to "Korakuen" in branches of the aqueducts (Fig. 5).

Another connection type to garden ponds from canals is found in Obata, Kanra, Gunma, Japan, as aque-duct system and garden uses are found together in the same network. This water network is complex and canals are divided many times in the village of Obata, Kanra, feeding directly to each house. 70.4% of canals in the net-work flow in private areas. This means that any route from upstream to downstream passes through a private area. However, there are many routes downstream with many diversions to reduce the risks of stopping the entire sys-tem through the activity (daily life use, having fishes for garden use) in each private area. 75 % of diversion points are placed in public areas to maintain overall control, and to prevent stopping or polluting that might be caused by errors made in a private area. This system can accept garden use with a direct connection from the canal (Fig. 6 and Fig. 11)

Connections between garden ponds and the water network in Kojirokuji is much simpler. Four main canals flow south to north, with branches to each garden that return water to the same canal. 68.1 % of canals in the network flow in public areas and canals in private areas are only parts of the downstream and upper stream. It means the main canals of the water system flow in a public area.

Diversion points to garden ponds in Edo are generally located in a private area. In Edo, 99.5% of garden ponds are connected to water networks with only one inlet, so that there is less flow in the garden ponds. Gates are only needed to control some water in gardens (closing and opening gates decreases the impact downstream). On the other hand, garden ponds in Obata and Kojirokuji are parts of the water network, closing and opening gates in gardens that influence the amount of water in the water network. So, most diversion points (78% of Obata, 100% of Kojirokuji) are placed in a public area to allow them to be managed from outside the gardens (Fig.7, Fig. 8, Fig. 9).

System for checking water quality in the network

The water quality in aqueduct systems needs to be checked daily for drinking and other uses. In old times, there were no machines to do so. The water network with gardens in Kojirokuji, a very simple network with two main streams and garden ponds, installed a water-checking system. The family who lived at the end of the network was one of the bureaucrats (Ito family), who would check water quality after it flowed through cities in garden ponds, a process that contributed to maintaining the high quality of public health in cities. A similar system is applied to Edo and Obata. The main castle of Tokugawa shogun (tycoon) family was placed almost at the end of the water network (Tamagawa aqueduct). The lord family (Oda family) also lived almost at the end of the water network (Table 2).

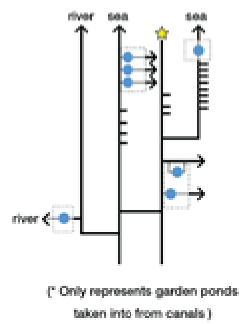
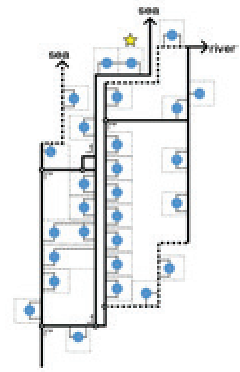
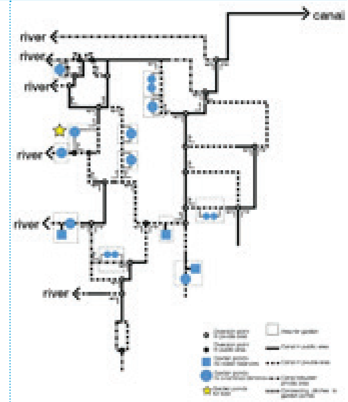
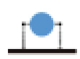
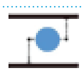
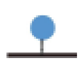
Diagram of water networks with gardens, Edo, Kojiro-kuji, Kanra.	Edo	Kojiro-Kuji	Kanra
			
Total length of canals (m)	-	1854	6020
Total length of canals, public ownership (m)	-	1263 (68,1 %)	1780 (29,6 %)
Total length of canals privare ownership (m)	-	591 (31,9 %)	4240 (70,4 %)
Division points of canals	-	6	16 (4 points in private area)
Confluent points of canals	-	3	18
Number of graden points	1454	28	17
Garden ponds and network			
Type 1 Divide and return to same canals 	1	25	10
Type 2 Divide and return to another canals 	0	2	1
Type 3 Divide and return at a some point 	1447	1	3
Type 4 Direct connection to garden ponds 	6	0	3
Garden ponds and topography			
Type A Garden ponds with slope 	181	0	5
Type B Garden ponds alongside slopes 	177	0	0
Type C Garden ponds without any slopes 	1096	28	12

TABLE 2 Diagram of water networks with gardens, Edo, Kojiro-kuji, Kanra.


FIGURE 7 The inlet point of garden pond from the river, in old Yasuda garden, Ryogoku, Tokyo


FIGURE 8 The diversion point of garden pond, Kanra.


FIGURE 9 The diversion point of garden pond, Kojirokuji.

FIGURE 10 Relationship between micro-topography and garden ponds in Edo.

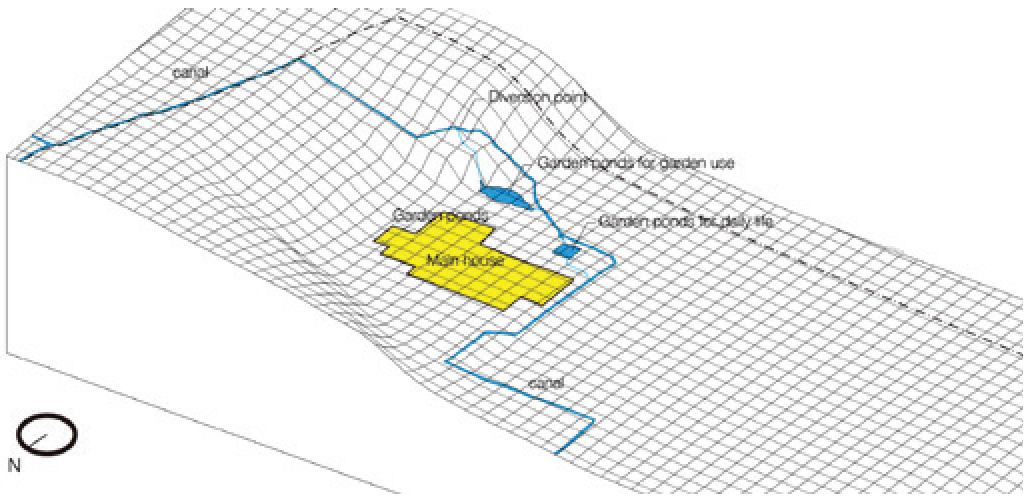


FIGURE 11 Relationship between micro-topography and garden ponds in Kanra.

FIGURE 12 Garden pond with piled stones wall to prevent to flooding.

Garden design as parts of water networks

Functional ponds and ornamental ponds in garden

Gardens ponds in Obata and Kojirokuji have two different needs: functional use and ornamental use in the same water network (Garden ponds in Edo are only used ornamentally with non-potable water). In five gardens in Obata, two garden ponds are set within one garden to realize both residential and ornamental functions. Garden ponds for ornamental use are shallow and horizontally spread with freeform shapes, located in front of the main house to be seen from the main guest room. On the other hand, practical ponds are deeper and rectangular-shaped, located near a kitchen and a toilet. Fish swim and eat remains of food, and then clean water in the functional ponds.

Design with micro-topography

The topography is not only important to the water network systems but also to the garden design. Micro topography is directly applied to garden design, such as a waterfall. Our measuring survey in Obata reveals the relationship between garden ponds in the water network and micro-topography. The entire village of Obata's has a gentle slope from north to south, and water networks were planned with the topography. Each garden has an average of 1 to 2 metre level difference; however, the large difference is applied to ornamental garden elements such as waterfalls, or mounds. It means that positions of garden ponds are defined with original micro- topography (Fig. 11). 24.6 % of gardens ponds in Edo, which has rich topography in the city area, are designed with micro-topography (Fig. 10). In Kojirokuji, the area is almost flat. However, walls of piled stones to prevent flooding are applied to garden designs (Fig. 12).

Conclusion

The aim of this research was to reveal the workings of hybrid systems with ornamental garden ponds and function-al water systems in historical Japanese garden cities of Edo/Tokyo, Kanra-Gunma and Kojirokuji-Nagasaki. This was done using the methods of researching old maps, documents, and measuring canals and garden ponds in three old cities and translating this into GIS data that could be analysed. This delivered the following important in-sights:

1. If over 50% of canals run through private land, canals are divided complicatedly to reduce the risk of stopping and polluting.
2. Lords of these cities lived at the end of the system to check whether the water quality of the whole water net-work was good or not.
3. In most cases, canals are not directly connected to garden ponds. In the few cases in which garden ponds have a function to control the amount of water downstream or upstream, garden ponds are directly connected.
4. Garden design variety increases with the topographical situation.
5. In gardens, canals are divided into different uses: ornamental use and functional use for daily life.

The gardens ponds that were part of the study all have access points to the water networks and were very much designed to be used in daily life by the people living around them. Diversions in a public area or garden area to sep-arate main streams and garden streams are important to maintain water quality. On the other hand, garden ponds including inlet points or outlet points, can control flows in water networks with gates closing or opening. Lords also have a necessary role in checking water quality in downstream networks. These systems were operated only by the traditional community in the early modern period when local lords controlled the local community system. Though the modern water system has replaced these water systems, the role of garden ponds as adjustment points or access points suggests green infrastructure as a flexible water system. Maintenance of these water sys-tems through active management of gardens by each residence gives us hints on how to solve maintenance prob-lems for modern water systems managed by governments. So, to apply green infrastructure to cities, it is im-portant to simultaneously cultivate communities with cultural life through green infrastructure, beyond maintenance activities.

References

Amasaki, H. (1984). Water network and garden ponds in Nanzenji-temple. *The Journal of Kyoto College of Art,* Kyoto

Inatsugi, T. (1990). 庭園と住居の＜ ありやう＞ と＜ 見せかた・ 見えかた＞ ― 日本・中国・韓国― *[Space and design about garden and houses in Japan, China and Korea].* Tokyo: Sankaido

Ito, S. & Morimoto, Y. (2003). Garden Ponds as Wildlife Habitats for Fish from Lake Biwa into Kyoto City. *Journal of The Japanese Institute of Landscape Architecture* 66(5) 621-626, Tokyo

Kim, Y., Ono, A., Zhang, J., & Mitani, T. (2017). A Study of the Spatial Composition and Elements in Korean Byeol-Seo Garden. *Journal of The Japanese Institute of Landscape Architecture* 80(5) 599-602, Tokyo

Kim, Y., Ono, A., Zhang, J., & Mitani, T. (2018). A Study on Enclosing Characteristics of Topography around the Korean Byeol-Seo Garden. *Landscape Research Japan Online* 81(5) 559-564, Tokyo

Mori, O. (1962). 寝殿造系庭園の立地的考察 *[A geographical study on gardens for Shinden-zukuri style architectures].* Nara National Research Institute for Cultural Properties, Nara, Japan

Ohashi, M., Mizuuchi, Y., & Ono A. (2019). A Study on the Planting Design of Ginkgo trees and the Process of Ginkgo trees Landscape Formation in old Yamazaki village in Inazawa, Aichi prefecture, *Journal of The Japanese Institute of Landscape Architecture* 82(5) 469-474, Tokyo

Ono, A. (2016). A study on Revetment Design of Canals and Gardens in Suzhou, China. *11th International Symposium on Architectural Interchange in Asia* 950-953 Sep, Sendai, Japan

Ono, A., Li, K, Zhang, J., & Mitani, T. (2012). A Study on the Spatial Composition between Garden Architectures and Garden Ponds in Suzhou, China. *13th International Symposium of Landscape Architecture, Korea, China, and Japan* 49-53, Suncheon, Korea

Ono, A., Li, K, Zhang, J., & Mitani, T. (2013). A Study on the Relationship between the Pond Waterside and the Garden Pavilion as a United Space Design. *Journal of The Japanese Institute of Landscape Architecture* 76(5) 497-500, Tokyo.

Ono, A. & Mitani, T. (2010). A study on the Relationship between the Topography and Gardens in Edo. *UIA2011TOKYO Academic Program* 103-108, Tokyo.

Ono, A. & Kim, Y. (2018). Redefining an Abandoned Old Aqueduct System As Green Infrastructure: I*FLA World Congress,* Singapore.

Ono, A. & Kim, Y. (2018). A Study on Renovation of Historical Green Infrastructure in Tokyo, Japan. *The 12th ISAIA 2018 Pyeongchang Korea,* p2071-2074, Pyeongchang Korea.

Sasaki, K. & Nagai, Y. (2016). *Recent Changes of Watercourses Supporting the Pond of Garden at Matsushiro, Castle Town, in Nagano City.* The Academic Society of Japanese Garden, 1-10, Tokyo.

Steenbergen, C. & Reh, W. (2003). *Architecture and Landscape: The Design Experiment of the Great European Gardens and Landscapes,* The Netherlands, Birkhauser.

Yamaguchi, K., Nakashima, K., & Kawasaki, M. (2009). Characteristics of Scenic Views and Topographic Enclo-sure of the Traditional Gardens in Kyoto, Japan. *Society of Civil Engineers D* 65(3), 317-328.

The Watermills of the Sierra de Cádiz (Spain)

A Traditional *Open* Water Re-circulation System

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Abstract

Traditional hydraulic milling was the main productive activity in the Sierra de Cádiz (Andalusia, Spain), as evidenced by the existence of 85 mills spread throughout the region. Although the date of their construction is unknown, the first documentary evidence of their existence appeared in the 16th century. In the 18th century, a more comprehensive account of the set of mills in the Sierra was drawn up thanks to the Ensenada Cadastre. The majority were operational until the mid-20th century, albeit with some difficulties. The disappearance of this handmade trade has led to the obsolescence and abandonment of its architecture and infrastructure. However, the infrastructure remains there, as traces of a recent past in which it is still possible to see the *Circular Water Story* that made them work. This article explains the hydraulic system that was used by the mills in the Sierra de Cádiz. Located next to rivers and streams, they formed part of an *open* water re-circulation system, which captured the water at a specific point in the riverbed of origin, artificially diverted it to the mill and then ended up returning it to the same riverbed of origin, at a different point from the initial one. The methodology used is based on the preparation of graphic documents and photographic recognition to select the riverbanks that show the adaptations and variations of the water re-circulation system according to the hydrographic, topographic, and productive characteristics of each territory. As some of these old artificial riverbeds are still operational, today they are used as a natural resource to supply water to other productive activities, thus proving the usefulness of the system, the suitability of the construction techniques applied, and their consequent integration into the landscape. The research carried out justifies the need to protect and catalogue these architectural hydraulic systems before they disappear completely, in order to benefit from the learning that can be derived from the reading, interpretation, and transformation of the territory and its landscape.

Keywords

watermill; pre-industrial architecture; rural infrastructure; rural landscape; hydraulic circuit; traditional water system; circular water stories; landscape architecture.

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Introduction

Pre-industrial rural communities have been characterised by their symbiotic relationships with natural resources, which were used to farm the land and obtain raw materials from their surroundings, transforming them into basic commodities that enabled the communities to survive. According to M. Hough (1990), "a valid design philosophy, ... tied to ecological values and principles; ...; to the essential bond of people to nature, and to the biological sustainability of life itself" (p. 179). This applies to the conversion of grains into flour and bread. This process inspired several inventions, in each case generating specific architectural systems and infrastructures that create a dialogical physical-territorial connection and which, at the same time, have shaped and developed the landscape.

The study of these currently abandoned systems is extremely interesting due to the set of values they represent—they reflect architectural, ethnological, and landscape values, but also functional, constructive or strategic ones, all expressing the appropriate relationship of the architectures with their environment and the essential use of local resources available for the development of their activities. Therefore, as stated by M. Vellinga (2013), these structures are "increasingly identified as a repository of traditional knowledge that may be of value in contemporary attempts to develop more sustainable built environments" (p. 570).

FIGURE 1 Location and agricultural regions of the province of Cádiz. Elaboration according to the Ministry of Agriculture, Fishing and Food.

This article originates from a more extensive study focused on the hydraulic flour mills of the Sierra de Cádiz[1], in Andalusia, Spain (Fig. 1). Milling was their main productive activity in the mountainous region, a markedly rural, artisan environment, historically isolated and dominated by small, white villages, scattered buildings, and small properties, with 85 watermills dispersed throughout the Sierra de Cádiz, many of which are still standing but are now abandoned and in a poor state of preservation. This fact is explained by the orographic and cultural features and heavy winter rainfall, which gives rise to a significant hydrographic network, with a capillary network of numerous fast, low-flow streams that run through the region forming a resource that irrigates the entire province. The Guadalete and Guadalporcún rivers are the main rivers that structure the territory of this region and, together with the rest of the streams and tributaries, they determine the different riverbanks where the hydraulic flour mills are located (Fig. 2).

1 Sierra de Cádiz is one of the five agricultural districts established by the Ministry of Agriculture, Fishing and Food for the province of Cádiz; the district has an area of 105,435 ha and has 14 municipalities: Alcalá del Valle, Algodonales, Benaocaz, El Bosque, El Gastor, Grazalema, Olvera, Prado del Rey, Puerto Serrano, Setenil de las Bodegas, Torre Alháquime, Ubrique, Villaluenga del Rosario, and Zahara de la Sierra.

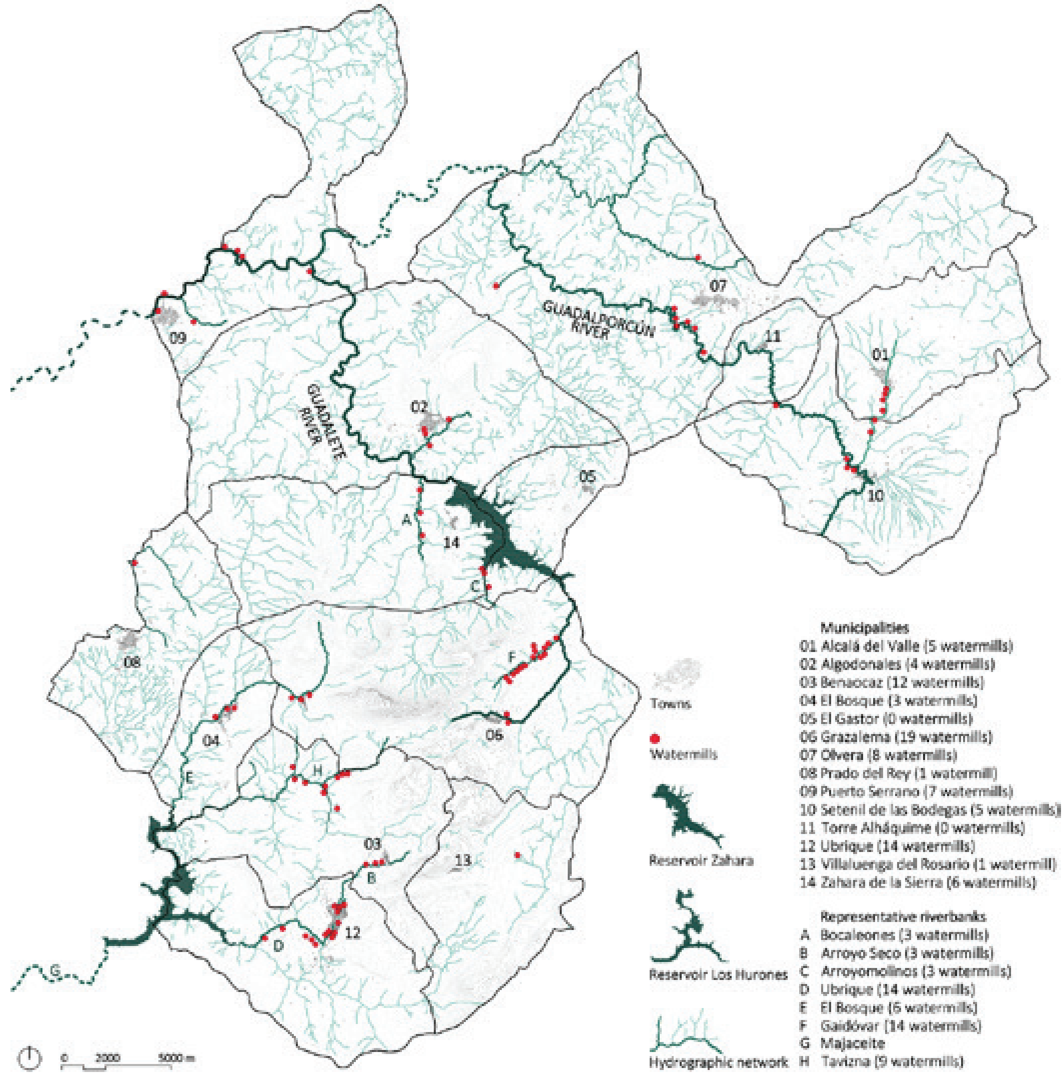

FIGURE 2 Map of the physical and territorial environment of the Sierra de Cádiz: topography, hydrography, and municipal districts. Location of the hydraulic mills according to the riverbanks and mountain municipalities that make up the Sierra de Cádiz.

Historical Context and Brief State of Affairs

Although previous evidence had been found of the existence of the watermills (Derry & Williams, 1977), it was not until the last two centuries of the Roman Empire that they became more widely used by the ruling countries (Holt, 1990). However, in Spain, the first document to refer to a watermill dates from the 10th century (Escalera Reyes, 1983, p. 28), though it was only after the 13th century that they achieved major expansion, most probably due to their dissemination carried out by the Arabs (García de Cortázar, 1974, pp. 180-181).

Regarding the Sierra de Cádiz, the foundation and settlement of this region has two major phases: the stage when the mountain range was under Muslim rule (8th to 13th centuries), and the stage following the conquest and recovery by the Crown of Castile (13th to 15th centuries).

The mills in the Sierra de Cádiz are not chronologically dated. Although there are Phoenician ruins in the region and some of these built-up areas have been linked to Roman settlements (Suárez Japón, 1982, p.

319)[2], the origin of the majority of their communities lies under Muslim rule.[3] Therefore, it is very likely that they were the first settlements of Muslims who, as of the 8th century, imported their horizontal-wheeled watermills, which are less technically complex than those with vertical wheels that had gradually replaced the horizontal-wheeled mills throughout the Middle Ages, except in those mountainous and isolated areas whose orographic conditions meant that the horizontal-wheeled mills had to be maintained, such as in the Sierra de Cádiz. The first documentary evidence of the existence of mills in the area can be found in a clause dated 26th February 1584, contained in the *Municipal by-laws archive of la Villa de Zahara* (Escalera Reyes, 1983, p. 42), which reveals that their existence was common at that time, which must be why, in the 16th century, the mills were fully integrated into the way of life of the Sierra. At that time, many of the watermills in Europe drove the complex structure of monopolies, privileges, and banal rights that characterised the feudal regime, as they were a major economic and vital source for the community. Nonetheless, in areas where the feudal power was not so strong, such as in the Sierra de Cádiz[4], there were small mills "whose occupancy and use would be of a communal, neighbourly or family nature" (Escalera Reyes, 1983, p. 36). In the 18th century, we can find a more comprehensive account of the watermills thanks to the *General Answers* of the Ensenada Cadastre (1750Đ1754), through which we now know that there were 61 flour mills in the region due to textual and sometimes graphic descriptions (Fig. 3). Second to these, the Planimetric Surveys of 1873-1874 are the most accurate historical cartography that has allowed us to count the watermills in the region, since they coincide in time with their period of maximum operation. These documents, contrasted with the fieldwork, have been fundamental in locating the 85 watermills that are still in existence[5].

In the Sierra de Cádiz, the watermills were kept in full operation until the beginning of the 20th century, with the exception of 4 watermills (in the municipalities of Algodonales, Grazalema and Zahara de la Sierra) to which 6 bakeries were associated (Escalera Reyes, 1983, pp. 152-154). This was unusual, considering the general closure of flour mills in Spain during the first half of the 20th century, when the ultimate transition towards economic modernisation took place (demographic growth, technological innovations in the second half of the 19th century, improvements in agricultural activity, etc.). After the introduction of the Austro-Hungarian milling system (from the 1878 Universal Exhibition in Paris), traditional mills gradually disappeared and were replaced by flour mills: in the period from 1856 to 1900 alone, the number of mills recorded in Spain fell by 22%, while the number of flour mills rose from 82 to 712 (Nadal Oller, 1992, p.161). After the Civil War they experienced an upturn in their production, paradoxically due to the grain control and rationing policy of the Franco regime, systematically infringed by the mills in the Sierra in light of the post-war shortages, when bread was a staple and essential food for the rural and farmer community. The mills of the Sierra continued to mill in secret, evading the policies that ordained their closure and dodging the inspections of the Tax Prosecution Office and the National Wheat Service, with the help of the complex topography of the Sierra, well known by the millers. In this way, the millers overcame the obstacles of the interventionist policies, but there were other factors that caused their ultimate downfall, such as the competition of flour mills, the abandonment of farmhouses and ranches, and the depopulation of rural areas whose people were their main consumers or "clients", the overcoming of the subsistence economy that characterised the Sierra, or the progressive decline of the crops in favour of livestock specialisation (Escalera Reyes, 1983, p. 49).

2 Hippa in Olvera, Laccipo with Setenil de las Bodegas, Ocurri with Ubrique and Benaocaz and Lastigi with Zahara de la Sierra.

3 Benaocaz, Grazalema, Olvera, Setenil de las Bodegas, Torre Alháquime, Ubrique, Villaluenga del Rosario and Zahara de la Sierra.

4 Due to their Muslim past and because, after their conquest and integration in the Crown of Castile, the lordships in which these lands were integrated were always based in other towns and cities, and they only built a recreational estate, which is the origin of the current municipality of El Bosque (Pérez Ordoñez, 2009, pp. 124-125).

5 For more information on the use of the Planimetric Surveys to locate water mills in the Sierra de Cádiz, see: Rivero-Lamela & Ramos-Carranza (2019).

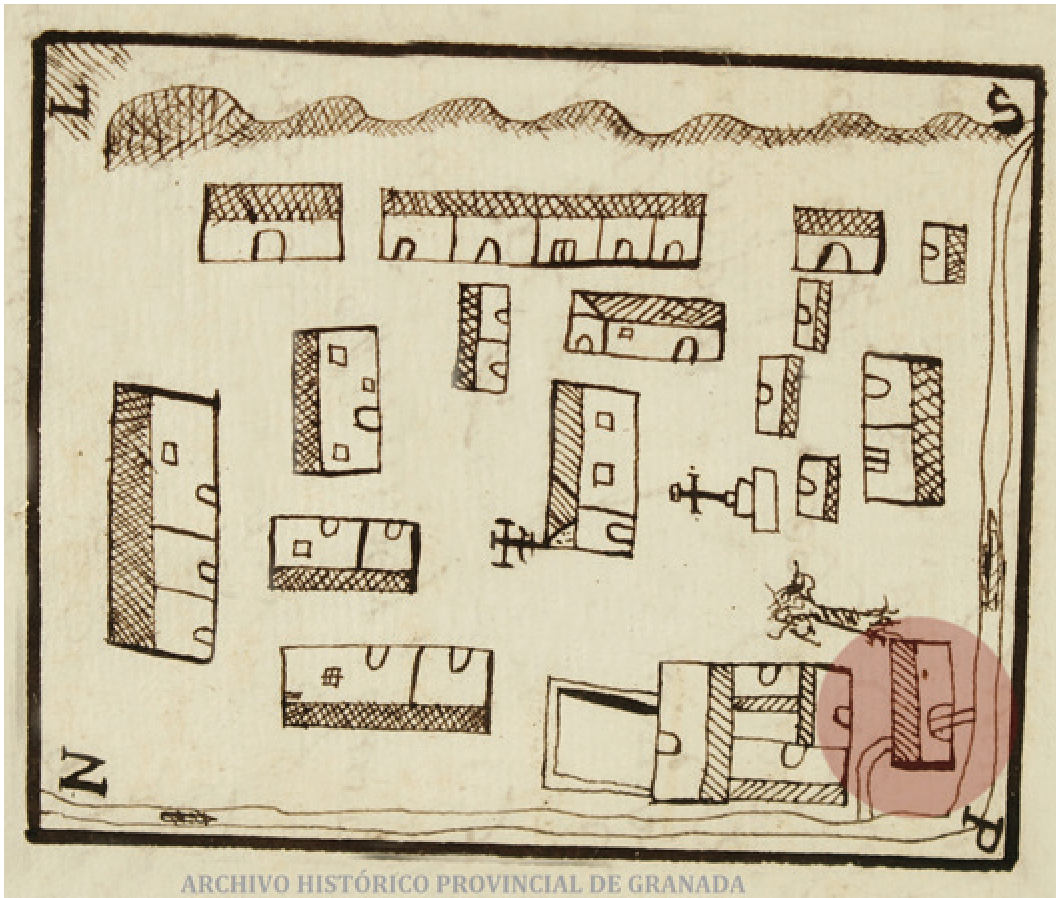

FIGURE 3 El Bosque (Marchenilla), as seen in *Autos, respuestas generales y estados de El Bosque*. Ensenada Cadastre. 1753-1754. Symbol: D-L/1513. Image by Archivo Histórico Provincial de Granada (Historical Archive of the Granada Province) Reprinted with permission.

Taking their current inactivity into account and the fact that many mills are in a complete state of ruin, this study aims to understand how these hydraulic mills worked in relation to their activating channels—rivers and streams—, in order to draw conclusions that may be useful in current water management practices and landscape projects in the region or in other similar geographical areas. Their lack of cataloguing and cultural interest is due to the fact that they have been considered as constructions whose purpose justified their existence, being forgotten when they were no longer indispensable. It is interesting to note that the current state and local maps do not show any of these old mills.

There is growing literature on the study of these types of mills, but it is still fragmented. In the international context, Adam Lucas' monograph (2006) serves as a reference point, providing a general outlook of milling in ancient and medieval societies, and showing the continuity in the use of the horizontal wheel. The works by Colin Rynne (2013) for Western Ireland can also be mentioned. The fact is that the horizontal-wheeled mills are technically the oldest hydraulic devices. The different types in existence vary depending on how they obtain the amount and force of water required to make the wheel turn. When it was not possible for the wheel to directly enter the river because of its insufficient flow or speed, the construction of artificial waterfalls or dams became necessary. In these cases, the water had to be captured and carried to the point capable of creating a strong jet of water, which was achieved in different ways through irrigation channels, channels at a higher point, or vertical or inclined shafts or buckets, as shown by the works of E. Veiga de Oliveira (1967) or A. Jespersen (1953).

In the Iberian Peninsula, there have also been numerous studies on water mills with horizontal waterwheels or vertical wheels. However, few works approach the issue from an architectural and infrastructural perspective that connects the mills to their riverbanks, or that conceives them as a territorial system of water circulation, and that uses planimetric drawing as a methodological tool. Some examples along this line have been developed in the north-west of Portugal (Matos, 2011; Matos & Barata, 2016; Silva Costa, Lopes Cordeiro, Batista Vieira, & Vaz, 2016), in the Basque Country (Izaga Reiner & Herreras Moratinos, 2016), in Segovia (Sanz Elorza, 2012), in Seville (Sánchez-Jiménez & González, 2018) or in Granada (Reyes Mesa, 2000), but none has focused on the Sierra de Cádiz region.

An *open* hydraulic re-circulation system

All the flour mills in the Sierra de Cádiz shared the same formal, spatial, and constructive characteristics, and basic infrastructures for their operation. Each had a horizontal waterwheel and a channel to divert water from the stream, bypassing the topography and carrying it to the buckets (penstock tower) –one or two–, a channel that enabled the water to fall with enough power to drive the waterwheel. Additionally, some had ponds, which gathered the water in case of a lack of river flow. Once the mill mechanism was activated, the water returned to its natural course due to the strategic location of the mill, which was always close to the stream. This generated a *circular water story*, a pseudo-natural circuit that derived from the logical interpretation of the natural conditions of the environment. According to British historian A. Keller (1984), the "molino de cubo" (bucket mill), as it is referred to in Spanish, comes from the Arabic *arubah*. Ancient ruins of this kind have been found in Israel, as is highlighted by S. Avitsur (1960), and their structure (Fig. 4) is very similar to that of the mills in the Sierra de Cádiz that we have described.

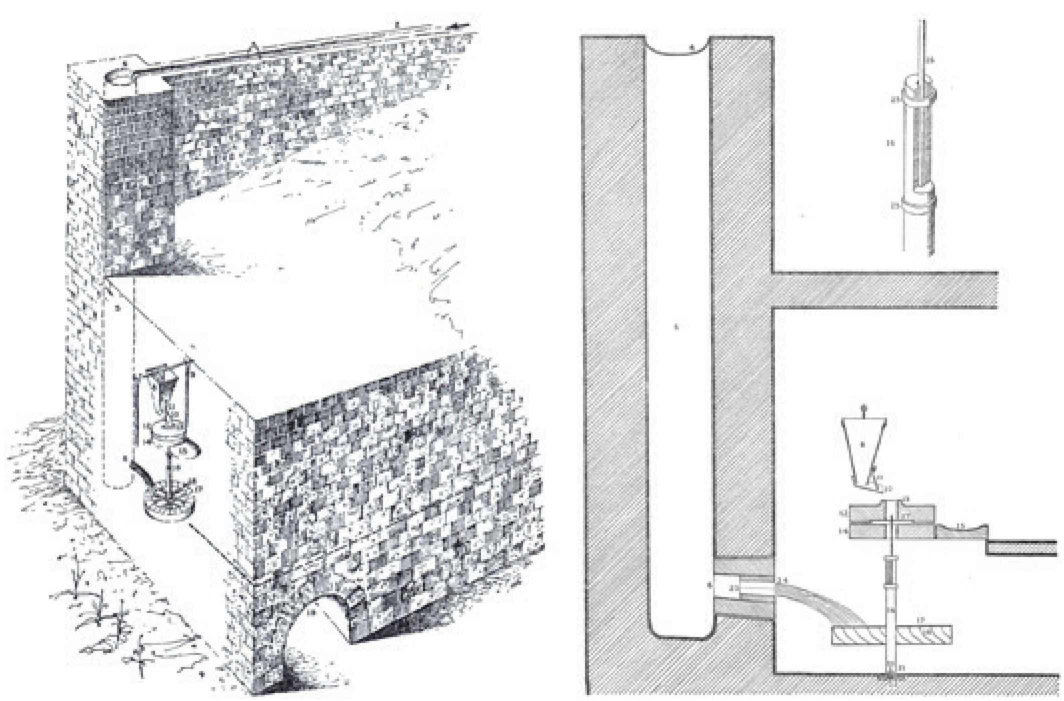

FIGURE 4 Structure of an ordinary *arubah* penstock mill (Avitsur, 1960, pp. 42-43).

There is an invaluable Spanish manuscript from the 16th century by Pedro Juan de Lastanosa known as "The Twenty-One Books of Devices and Machines", in which the bucket mills are described and drawn, which may or may not already have a pond (Fig. 5).

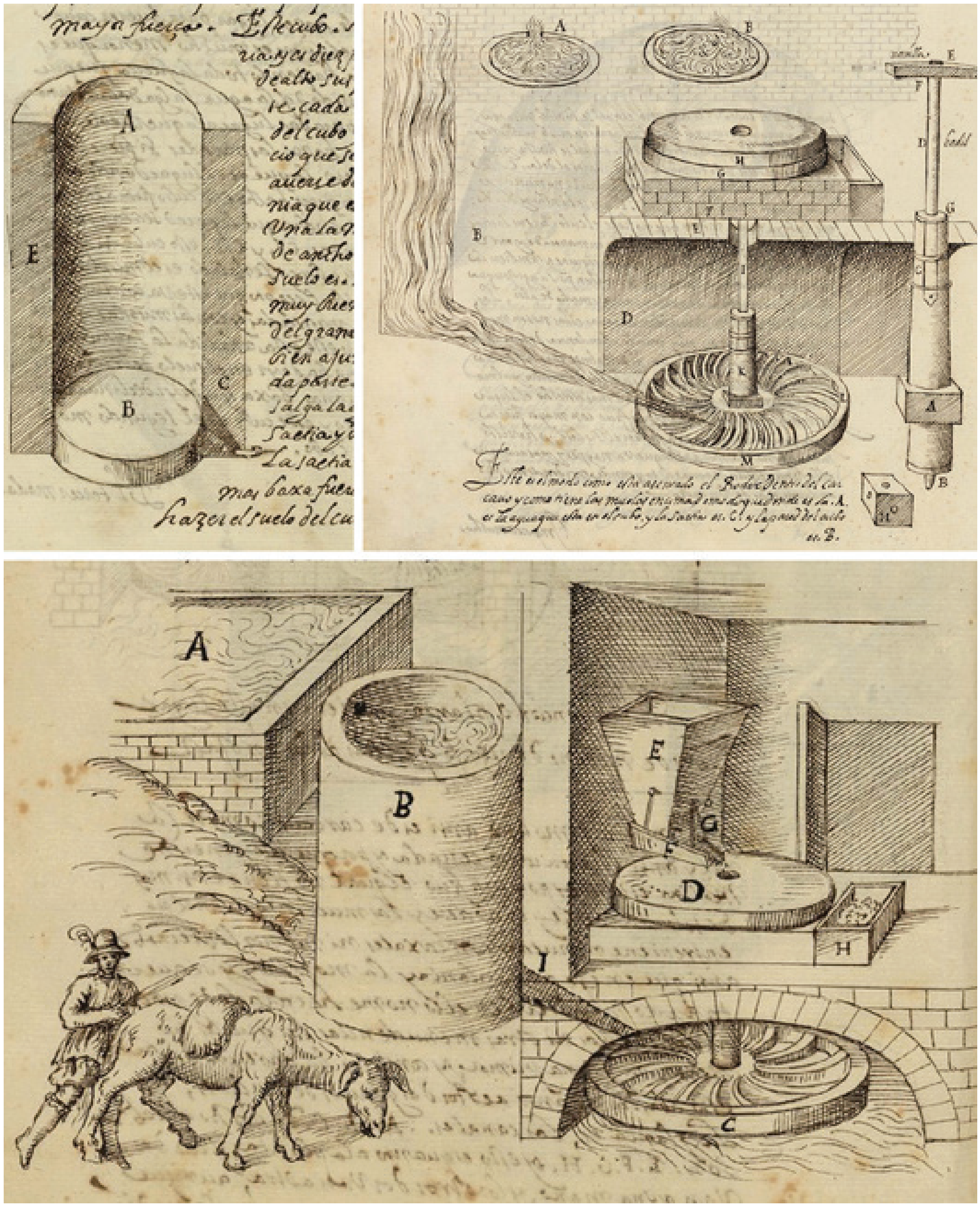

FIGURE 5 Bucket mill in the 16th-century manuscript “The Twenty-One Books of Devices and Machines” by Pedro Juan de Lastanosa. Images property of the Biblioteca Nacional de España [Spanish National Library].

The work already carried out to locate all the mills in the region and their study at riverbank level allows us to understand their operation as open re-circulation systems of water resources. In other words, the mill or group of mills are not a cyclical—and therefore closed—system that starts and ends at a geometric point; these mills are connected at the exact point to create an artificial but innocuous circuit, which captures the water and directs it towards the mill, in a route that ends in the same riverbed of origin, downstream, at another point different from the initial one. It is, therefore, a system of re-circulation of surface water that depends on the natural course of the stream itself to complete the technical process of using, exploiting, and returning the water (Fig. 6).

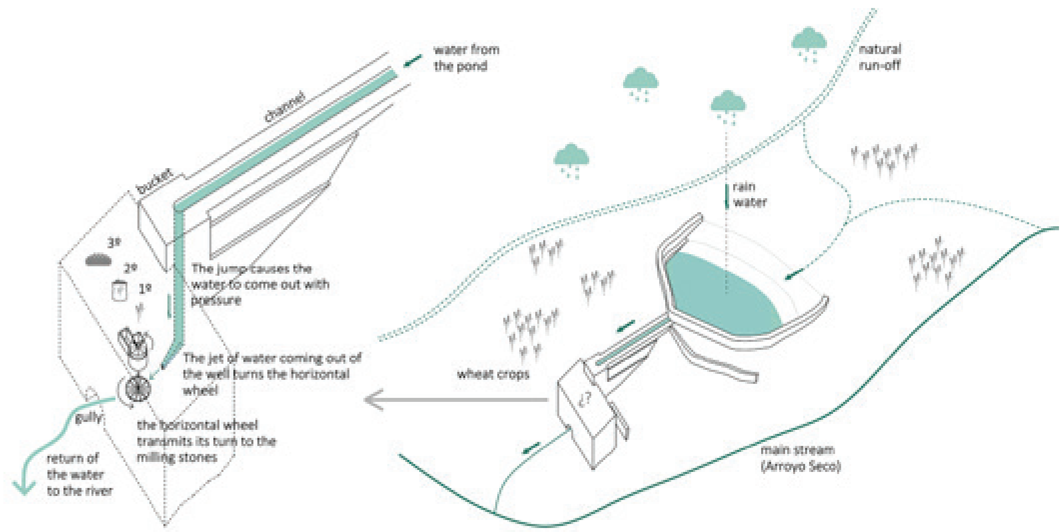

FIGURE 6 Functional diagram of the mill, drawn according to the ruins found. Second mill (B-02), riverbank of Arroyo Seco, Benaocaz.

This circular use of water allows for the introduction of different variations that made this generic scheme a more complex system due to the physiographic and climatic singularity of the Sierra de Cádiz. This created an extensive hydrographic network which, together with numerous roads and communication routes, also adapted to the topography, connected mills, cropland, and pasture land, communities and other scattered buildings. This idea of connectivity through the communication and water infrastructures was transferred to the water re-circulation system, as in various riverbanks just one riverbed would activate various mills and would also irrigate the nearest crops.

We consider that the analysis of the mills' architecture and its connection to the land is an appropriate way to explain the interrelationship with the river and other natural elements. We perceive the different water re-circulation circuits as parts of a larger system: the mill structure created around a specific riverbank, which strategically distributes the mills and their hydraulic infrastructures along the riverbed and, from a larger perspective, the mill configuration of the whole region.

Methodology

The research method is straightforward to explain and complex to implement. It is based on understanding the different scales that coexist around the mill building and its water circulation system to try to extract all possible knowledge. In this sense, this methodology allows for a scope of research that includes the relationship between different scales of work and addresses the implied link between technologies, cultural contexts, and efficiency that historian P. Oliver (2006) deems necessary for the full understanding of the fact or reality to be analysed: "To understand the full implications of the technologies used, it is necessary to consider them in relation to their cultural contexts, as well as in terms of their efficiency or performance" (p. 122).

Thus, after locating 85 mills by analysing the historical cartography and completing it with exhaustive fieldwork, it was possible to verify the different contexts, territories, and states of conservation of the mills. These factors justified the selection of the representative riverbanks of the region in which the hydraulic milling system, the circularity of the water, and the productive operation would be studied in detail.

The analysis of the mill banks of the Sierra de Cádiz revealed different water re-circulation systems: systems that need ponds in order to prevent the consequences of the lack of flow from the stream or river due to the insufficient rain in summer periods (the riverbank of the Arroyo Seco, located in Benaocaz); systems in which the channelled water is also used for the irrigation of nearby agricultural land (the riverbank of Bocaleones, located in Zahara de la Sierra); and finally, water circulation systems used by several mills (the riverbank of Gaidóvar, in Grazalema).

Arroyo Seco Riverbank

On this mill bank (Fig. 7), the only constructions that have been in existence since the 19th century are three mills that are dependent on the Arroyo Seco, whose name ("dry stream"), reveals the scarce quantity of flowing water, not enough to guarantee the mill's operation throughout the year. The scarcity of water explains the current absence of farmland. The wheat, barley, and rye plantations (dry crops) that existed there, according to the 1873 Planimetric Surveys, have become unproductive lands used for pastures.
The irregular flow of the Arroyo Seco forced the mills to provide their own infrastructure to guarantee the continuous supply of water: these are the ponds that precede the channel that ultimately carried the water to the mill. The position of these ponds, as can be seen on the map (Fig. 7), was built in line with the topography to take advantage of natural runoff from the rain, whose water is added to that which could be obtained by artificially diverting the bed of the Arroyo Seco in times of enough flow. There is no physical evidence of a connection between ponds and the river, but it is likely that there are unbuilt surface channels (diversions), these being mere ditches dug into the ground.

It was, therefore, a double water collection system that made the most of the natural efficiency provided by the topography and the rainwater runoffs, thus increasing the natural functioning of Arroyo Seco as these ponds were converted into small natural waters accumulators which, once used for milling, were returned to the stream and improve the mill's operation.

FIGURE 7 Arroyo Seco Riverbank, in Benaocaz. Presence of 3 hydraulic mills (from left to right): B-03: El Pontón Mill, B-02: Second Mill and B-01: First Mill.

To the north of the stream, a path that runs parallel (called “Cañada de Piedras”) gives rise to a strip of land divided into rectangular and elongated plots: this optimises the rights of way and the benefits derived from the river. These plots are transversally divided by two water lines located very close to the surface which, it seems, helped to store water in the mill ponds (drawn on the map of Fig. 7 with dotted blue lines. On one of these it says “natural run-off”; currently this constitutes ditches created by erosion after rain).

The use of natural conditions and resources minimised the transformation of the landscape by reducing the construction of channels for water collection, which is why these mills were located in front of or at the side of the riverbed. Each had a wheel, which resulted in moderate production, typical of an environment with a few scattered buildings and covering mainly the needs of the town of Benaocaz, 500 m from the First Mill (B-01).

At present, the three mills are in ruins, which influences the level of conservation of the roads mentioned. However, the remains of their infrastructures still allow the hydraulic system that made them work to be determined. At their lowest point, the ponds were connected with the channels, whose length varied according to the distance at which the mill was located and the topographical unevenness. This explains the function of the bucket and the position of the mill: the bucket had to be placed in the area of greatest unevenness so that the natural fall of the water generated sufficient force to move the horizontal wheel; the mill had to be placed as close as possible to the riverbed to ultimately return the water to the natural course of the river (Fig. 8).

In the case of El Pontón Mill (B-03), its location allowed it to fill the pond directly due to the free fall of the water, although this meant that there was a greater distance between the mill and the pond. In this case, the length of the channel turned the mill infrastructure into a sort of dock that linked both arms of the stream, benefiting from the difference in height between the pond and the mill, which then allowed the waterfall to turn the horizontal wheel.

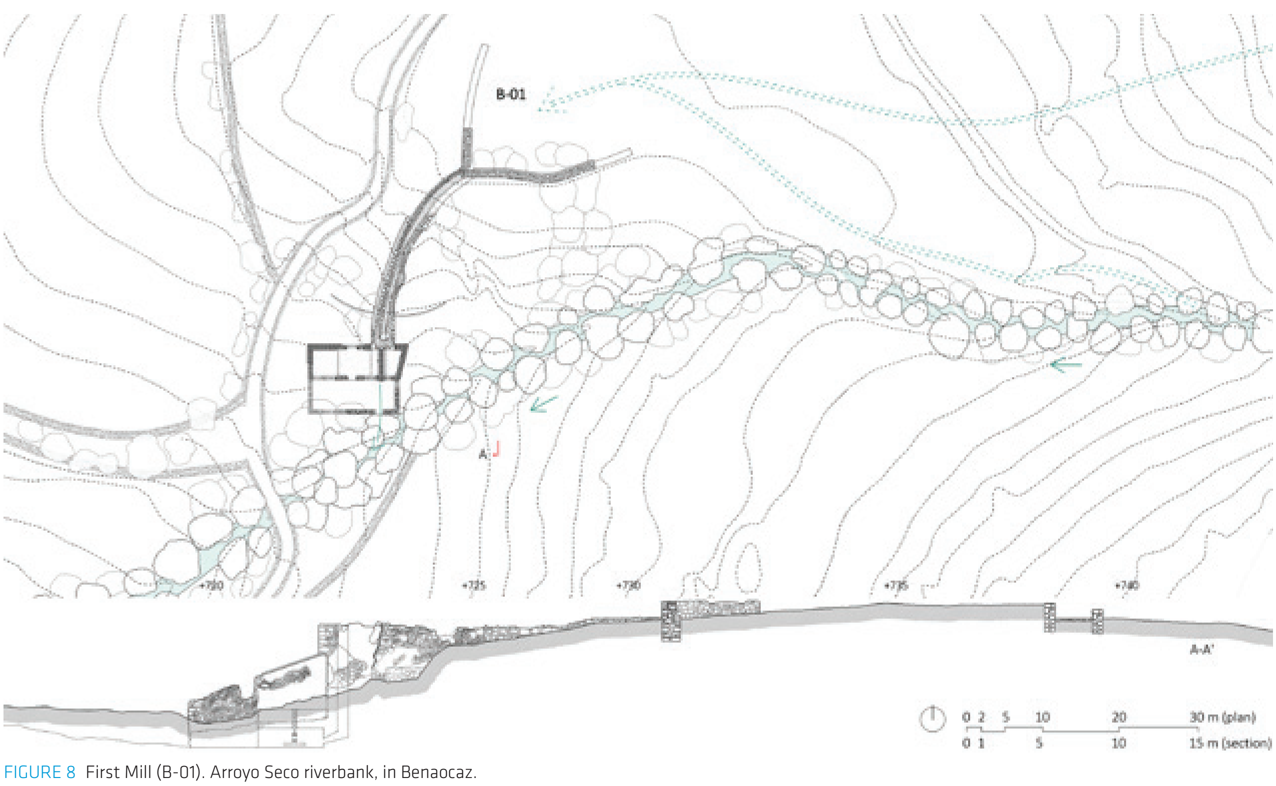

FIGURE 8 First Mill (B-01). Arroyo Seco riverbank, in Benaocaz.

Regarding the months of operation of the mills and whether they were seasonal or operated throughout the year, it is not possible to find this information. The mills of this riverbank have been abandoned for decades and we do not have any first-hand testimonies. The only document that makes reference to this aspect is the Ensenada Cadastre (1750-1754). In its response to question number 17, it accounts for six flour mills in the locality (through our fieldwork we have located twelve mills), and says that two of them "mill in winter when there is a lot of rainfall", with another three "using the river water, occasionally stopping" and the remaining one "using the river water". We do not know whether it is referring to the mills of the Arroyo Seco, although it is unlikely that they only milled in winter, because those are the mills that are within the closest proximity to the municipality of Benaocaz. We shall aim for the hypothesis that they also milled in summer thanks to the ponds, though on a more occasional basis.
In terms of the production of these mills, this is an aspect that is difficult to measure as it depended on the number of wheels that the mill had and on the period in which it was active each year. The Ensenada Cadastre, again in response to question number 17, mentions the annual income that the six aforementioned mills generated: the one that mills throughout the whole year produces "44 fanegas[6] (bushels) of wheat", the two that only mill in winter produce "6 fanegas of wheat" and those mills whose production is sometimes stopped produce "between 20 and 24 fanegas".
One thing we can say for certain is that they were essential for the rural community to survive. The mills of the Sierra de Cádiz were "maquileros", which means that they could not officially buy or sell wheat or flour, and they were limited to milling the wheat that was brought to them by farmers or individual locals in exchange for the "maquila", which is the payment in kind –generally flour– or money to remunerate the work of the miller.

Bocaleones Riverbank

Despite its distance from the town (3 km), this has always been an inhabited and cultivated riverbank, a fact that can be confirmed by the historical cartography and the presence of three mills, one of which has now completely disappeared—which is why only two appear on the map in Fig. 9.

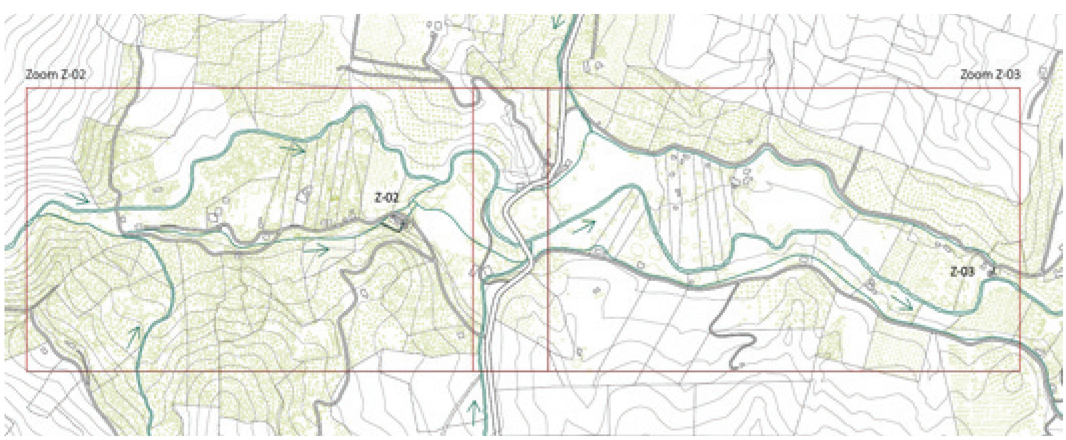

FIGURE 9 Bocaleones riverbank, in Zahara de la Sierra. Presence of 2 hydraulic mills (from left to right): Z-02: Bocaleones Mill and Z-03: Flour Mill.

6 A fanega (bushel) is a unit of measurement from traditional Spanish metrology, which in Castile equates to 55.5 litres, although this varies depending on the region.

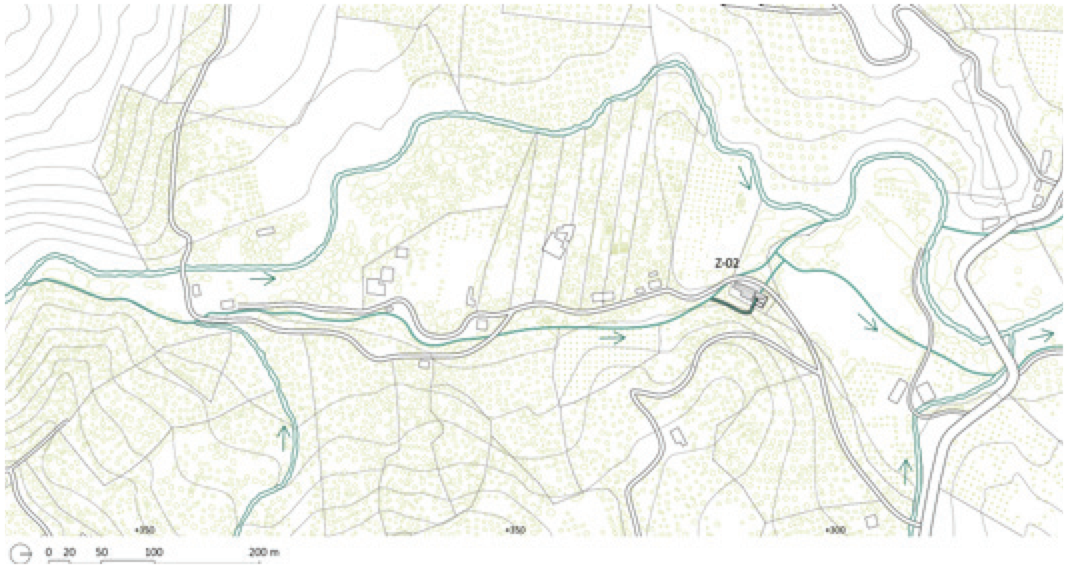

FIGURE 10 Surroundings of the Bocaleones Mill (Z-02).

None of the mills on this riverbank has a pond, which indicates that Bocaleones was a river with sufficient and regular flow throughout the year. The hydraulic system of the mills—the irrigation channels, together with the roads and the stream, structured the whole valley and determined land distribution, communications and irrigation systems, giving rise to productive land.

The first irrigation channel (the one furthest to the south) emerged from the riverbed at +300 m and ran for about 820 m until it rejoined the river, downstream at +285 m. Its function was—and still is—to irrigate all the agricultural plots on both sides. A second circuit (or second irrigation channel) emerged from this main channel and was responsible for feeding the Bocaleones Mill (Z-02), whose water discharged from the gully was channelled again through a channel that ran along the right bank of the stream, parallel to one of the paths that runs along this bank, and whose only function was to irrigate the crops. It was, therefore, a diverse system of water circulation; in this case, the mill took advantage of the water management needs of an agricultural environment. The synergy between milling, cultivation, and irrigation created benefits that were greater than their individual action. (Fig. 10).

The channel that fed the Flour Mill (Z-03) measures 1113 m, from the point where it connected with the Bocaleones stream at +280 m until it ended at a height of +275 m. In this way, a surface circuit was created on the left bank of the stream. This circuit acted as a cut or dock and fulfilled the functions of watering the land as it passed and bringing the water to the mill at the right level. The channel ran again parallel to the path, and both, as on the other bank, adapted to a certain height for greater ease of construction (Fig. 11).

This system meant that the plots of land delimited by rivers and channels were shaped with little width and greater depth, in order to achieve the least possible easement. The repercussions of the hydraulic infrastructures in which the mills operated can be seen in many of the anthropic layers that make up the current landscape of this riverbank.

Infrastructure and architecture become an essential and necessary link to enable the life and operation of the riverbank. As stated by Professor J. M. Palerm Salazar (2019), these types of actions on the land are a "product of people's experience … they build an evocative landscape in a way of linking to the land between walls, houses and roads" (p.17) with the intention of inhabiting a place.

FIGURE 11 Surroundings of the Flour Mill (Z-03).

Gaidóvar Riverbank

On this riverbank (Fig. 12), the water circulation system connected pairs of consecutive mills, in addition to being used for the irrigation of adjacent lands. Of the fourteen existing mills, none had a pond, and all had one wheel (less production but more mills), which shows sufficient river flow and controlled production to meet the needs of their surroundings. Pairs of mills could be found where the topography is a little smoother, just at the beginning of the riverbed. The first four, located at a higher altitude, were grouped and connected by their irrigation channels (G-01, G-02, G-03, and G-04, Fig. 13). The hydraulic system was the same in both mill pairs, except for the length of the surface channels. In both cases, they irrigated the crops on the surrounding land. These crops were flushed out, following the traditional technique for cultivating sloping soils. Once the mechanisms of these first mills was activated, the water discharged was led to the next ones. The system was repeated: once the horizontal wheel was activated, the water exited through the gullies of the G-02 and G-04 mills and gravity returned it to the Gaidóvar stream (Figs. 14 & 15).

The fact that the land adjacent to the mills was suitable for cultivation explains the layout and extension of the irrigation channel linking mills G-01 and G-02. The collaboration that enabled the construction of the channel and the optimisation of a natural resource such as water, speaks volumes about the local character of the region and the soundness of a channelling system built decades ago which is partially still maintained, despite the mills no longer being operational.

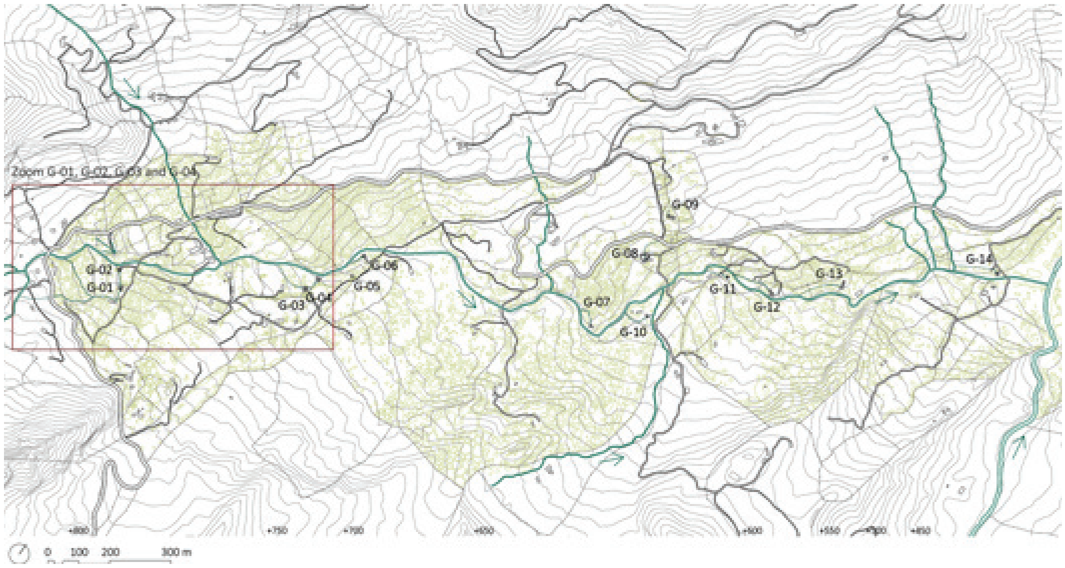

FIGURE 12 Gaidóvar riverbank, in Grazalema. Presence of 14 hydraulic mills (from left to right): G-01: La Cruz Mill, G-02: El Rincón Mill, G-03: El Pero Mill, G-04: El Portal Mill, G-05: El Algarrobo Mill, G-06: La Pasá Mill, G-07: El Caballo Mill, G-08: J. M. Chacón Mill, G-09: La Batana Mill, G-10: El Juncal Mill, G-11: El Zurdo Mill, G-12: El Pastor Mill, G-13: Caracol and G-14: Pataita Mill.

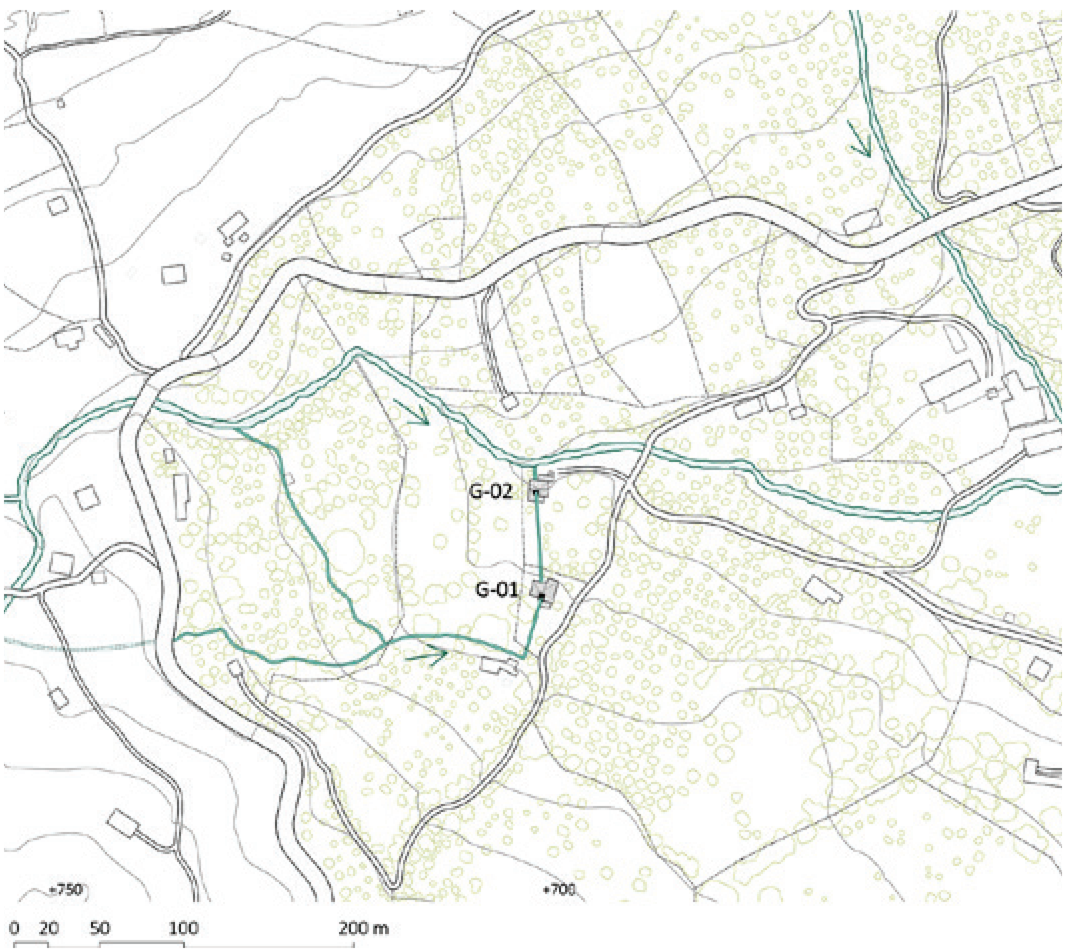

FIGURE 13 Surroundings of La Cruz (G-01), El Rincón (G-02), El Pero (G-03), and El Portal (G-04) Mills.

FIGURE 14 Section of the riverbank of Gaidóvar, in Grazalema. La Cruz (G-01) and El Rincón (G-02) Mills. Photograph taken by the authors via drone (2017).

FIGURE 15 Section of the riverbank of Gaidóvar, in Grazalema. El Pero (G-03) and El Portal (G-04) Mills. Photograph taken by the authors via drone (2017).

Water, Milling, and the Miller

The two factors that made this activity possible, beyond the milling mechanism itself, and that affected the social conditions and the stories of people involved with the mills, were the raw materials – grains, and the source of energy –rivers. These factors influenced their location and meant that the mills and the families that inhabited them were relatively isolated from the population centres.

Water is a vital element within rural communities. The artificial pipelines that the mills required covered, in numerous cases, many metres and crossed the lands of gardeners and farmers who benefited from this circumstance, using the channelled water to irrigate their crops. Each local resident was in charge of cleaning the stretch of irrigation channel that ran through their land, in the collective management of water carried out by the community, dependent on the intensive use of the hydraulic system that, in many cases, was regulated by the customary laws imposed on each riverbank (Escalera Reyes, 1983, p. 131), and which determined the time taken to distribute the water between farmers and millers.

The other factor, grains, was also an essential part of their location, as the wheat milled by each mill generally came from the surrounding lands, which made up their main area of activity.

In the Sierra de Cádiz, the mills were a family trade, and the miller, as a skilled tradesman, was indispensable and key to the life and economy of the rural communities. This was a "middle class" profession in rural areas, and for many years they were able to take advantage of the fact that they were the only sources of flour production available to make bread.

The milling process started with the transportation of the wheat to the mill carried out by a nearby local resident. First the wheat was weighed and then cleaned, washed, and put out to dry in the sun on mats, a task that was carried out by housewives, who also coordinated it with washing clothes by using the water that came out of the gullies. 16).

Once dried, the wheat was entered into the chute, and then it would fall onto the stones where it would begin to be milled until it became flour.

Generally, all of these tasks were carried out by the family itself, who passed on the knowledge of the trade from generation to generation. It was common for a family of millers to move from one mill to another within the same area, with the aim of finding a mill with a greater production capacity to thus improve their financial circumstances (Escalera Reyes, 1983, p. 168).

The productivity of each mill depended on the force of the water and the number of stones that it had. However, Escalera Reyes (1983, p. 137) establishes that production was greater in the harvesting seasons for wheat (June-August) and olives (November-December), as this was when the farmhouses and ranches were more inhabited by dry labourers, and estimates that the production capacity of the mills in the area was between one or one and a half fanegas per hour.

The investment and maintenance costs were minimal, and it was normal for there to be no employees and for the family of the miller to carry out all tasks, which meant that this trade was cost-effective and secure (Ordóñez Vergara, 1993), taking into account the ups and downs that the political future and industrial development caused in the 20th century, which led to many mills working in secret and sneaking in new tasks to increase their income.

FIGURE 16 Women and children around the El Rodezno Mill, in Ubrique (Sierra de Cádiz). Image by Romero de Torres, E. (1934, p. 45).

Conclusions

This study reveals the existence of a traditional hydraulic system generated by an economic activity and supported by the constructions and infrastructures that were needed for the operation of the flour mills in the Sierra de Cádiz. In this case, the functionality of any productive activity leads to very limited interventions that still tended to optimise the natural resources required by said productive activity. Understanding this criterion has been essential to understanding the location of the mills and explaining the layout of their various hydraulic infrastructures, as well as to understanding other parts that are necessary for their operation—such as ponds—on the riverbanks with rivers or streams of irregular water flow.

The use of water through what we have called an *open* water re-circulation system, is also developed from this logical way of using the resources available in a region that, for decades, was isolated or had difficulty connecting to other regions or nearby places. The cases in which various productive activities coexisted (cultivation and milling), or even those in which the physiographic conditions have forced a shared use of the irrigation channels and riverbeds, demonstrate the validity of this form of water circulation.

It is clear that technological advances and changes in production systems are normally the reason why certain activities end, especially when it comes to manual activities. The same necessity and functionality that made these mills necessary condemned them to be abandoned and forgotten, thus ending up in ruins and disappearing. The mills and the infrastructures that still remain, even those that are in ruins, should be protected and conserved because, in addition to representing to a cultural and historical time in the region, they represent an identity. These structures also allow an understanding of the use that we can give to land, the way in which it is possible to use local materials, the use of passive technologies, the incorporation of constructive rationality or the adaptation to natural factors (rivers, topographies, crops…). All these factors show a balance between resources and demands, and the integration between natural and anthropic aspects—guidelines that should be a priority in all territorial and landscape management and intervention. We should consider the strong potential offered by these mills, since they could be reincorporated into rural development through innovative approaches. Therefore, this would be a first step in viewing mills as a heritage network in need of protection and reactivation.

References

Avitsur, S. (1960). On the History of the Exploitation of Water Power in Eretz-Israel. *Israel Exploration Journal*, 10(1), 37-45, http://www.jstor.com/stable/27924809

Derry, T.K., & Williams, T.I. (1977). *Historia de la tecnología* [History of technology]. Madrid, Spain: Siglo XXI.

Escalera Reyes, J. (1983). Molinos tradicionales [Traditional mills]. In J. Escalera Reyes & A. Villegas Santaella. *Molinos y panaderías tradicionales* [Traditional mills and bakeries] (pp. 13-173). Madrid, Spain: Editora Nacional.

García de Cortázar, J.A. (1974). *La época medieval* [The medieval era]. Madrid, Spain: Alianza.

Holt, R. (1990). Milling Technology in the Middle Ages: The Direction of Recent Research. *Industrial Archaeology Review*, 13(1), 50-58, doi: 10.1179/iar.1990.13.1.50.

Hough, M. (1990). *Out of place: restoring identity to the regional landscape*. New Haven and London: Yale University Press.

Izaga Reiner, J.M. & Herreras Moratinos, B. (2016). Protección del patrimonio de las cuencas fluviales del País Vasco [Protection of the heritage of the river basins of the Basque Country]. In ACEM, *X International Molinology Conference*, Segovia, Spain, 333-345.

Jespersen, A. (1953). *A Preliminary Analysis of the Development of the Gearing in Watermills in Western Europe*. Virum, Denmark: Danske Boghandleres Kommissionsanst.

Keller, A.G. (1984). "Northern" and "Southern" Horizontal Watermills. In *Energy in History: 11th Symposium of the International Cooperation in History of Technology Committee* (ICOHTEC), Lerbach (near Köln), September 2 - 7, 1984.

Lucas, A. (2006). *Wind, Water, Work. Ancient and Medieval Milling Technology.* Leiden, Netherlands: Brill.

Matos, B. R. (2011). *Património à prova de agua. Apontamento para a salvaguarda das azenhas & açudes nas margens do rio Ave, Vila Nova de Famalicão/Trofa* [Waterproof heritage. Notes to safeguard water mills and dams on the banks of the Ave River, Vila Nova de Famalicão/Trofa]. Vila Nova de Famalicão, Portugal: Câmara Municipal de Vila Nova de Famalicão.

Matos, B.R. & Barata, F. (2016). Ave's watermills: Territory, Architecture and Construction Systems. *International Molinology*, (92), 22-29.

Nadal Oller, J. (1992). *Moler, tejer y fundir: estudios de historia industrial* [Grinding, weaving and casting: industrial history studies]. Barcelona, Spain: Ariel.

Oliver, P. (2006). *Built to Meet Needs. Cultural Issues in Vernacular Architecture*. Oxford, England: Elsevier.

Ordóñez Vergara, P. (1993). Los molineros de La Alpujarra [The millers of La Alpujarra]. *Gazeta de antropología*, (10), 13, http://hdl.handle.net/10481/13642

Palerm Salazar, J.M. (2019). Monotonous repetition in architecture. Terraced landscapes. *Proyecto, progreso, arquitectura*. Paisaje de Bancales, (21), 12-19, doi: 10.12795/ppa.2019.i21.12.

Pérez Ordoñez, A. (2009). *Sierra de Cádiz andalusí: Arquitectura y urbanismo islámicos en la frontera occidental del Reino de Granada* [Sierra de Cádiz Andalusi: Islamic architecture and urbanism on the western border of the Kingdom of Granada]. Spain: Lulu.

Reyes Mesa, J.M. (2000). Technology and popular architecture: Waterwheels in the province of Granada. *Gazeta de Antropolgía*, (16), 1-13, http://hdl.handle.net/10481/7516

Rivero-Lamela, G. & Ramos-Carranza, A. (2019). Drawing and interpreting Planimetric surveys: rural landscape and old productive architectures in Sierra de Cádiz. *Disegnarecon*, 12(22), 18.1-18.23, http://disegnarecon.univaq.it/ojs/index.php/disegnarecon/article/view/501/376.

Romero de Torres, E. (1934). *Catálogo de los Monumentos Históricos y Artísticos de la provincia de Cádiz.* Tomo 6 [Catalog of the Historic and Artistic Monuments of the province of Cádiz. Volume 6]. Madrid, Spain: Ministerio de Instrucción Pública y Bellas Artes.

Rynne, C. (2013). Technological Continuity, Technological 'Survival': the Use of Horizontal Mills in Western Ireland, c. 1632–1940. *Industrial Archaeology Review*, 33(2), 96-105, doi: 10.1179/174581911X13188747258748.

Sánchez-Jiménez, F.J. & González, J.A. (2018). Watermills: The Origin of the Use of Renewable Hydraulic Energy in Spain. *Industrial Archaeology Review*, 40(1), 2-10, doi: 10.1080/03090728.2018.1449383.

Sanz Elorza, M. (2012). *Ingenios con memoria. Recorrido por los molinos harineros de la provincia de Segovia y por la gestión tradicional de los recursos hidráulicos* [Devices with memory. Tour of the flour mills of the province of Segovia and the traditional management of hydraulic resources]. Segovia, Spain: Caja Segovia.

Silva Costa, F., Lopes Cordeiro, J.M., Batista Vieira, A.A. & Vaz, S. (2016). O estudo dos moinhos e aproveitamentos hidráulicos no Concelho de Lousada (Noroeste de Portugal)-Proposta de um guião metdológico [Study of windmills and hydroelectric power plants in the municipality of Lousada (Northwest of Portugal) - Proposal for a methodological guide]. In ACEM, *X International Molinology Conference*, Segovia, Spain, 407-418.

Suárez Japón, J.M. (1982). *El hábitat rural en la Sierra de Cádiz: un ensayo de geografía del poblamiento* [The rural habitat in the Sierra de Cádiz: an essay on the geography of settlement]. Cádiz, Spain: Diputación de Cádiz.

Veiga de Oliveira, E. (1967). Moinhos de água em Portugal [Water mills in Portugal]. *Geographica*, 3(9), 49-70.

Vellinga, M. (2013). The noble vernacular. *The Journal of Architecture*, 18(4), 570-590, doi: 10.1080/13602365.2013.819813.

Living with Nature

Water Stories of Kampung Naga, Indonesia

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Abstract

Rapid urbanisation and sprawling growth have become constant hindrances to nature in most developing countries. West Java is the most populated province in Indonesia under rapid urbanisation. In this rural area of the province, however, there is a traditional Sundanese hamlet called Kampung Naga that has succeeded in cohesively cohabiting with nature. This article discusses how the interaction of water, ecology, and anthropo-systems influences the spatial layout of the village, forms its cultural landscape, and shapes people's social life. In addition to its sustainability, this article also reflects on the challenges of the possible application of this heritage landscape system in wider contexts. Three lessons can be learned from the water heritage system of Kampung Naga: (1) Understanding how the workings of the natural landscape are critical in determining the living space development; (2) The circular water system and its metabolism could only be maintained by integrating it into its cultural, social, and economical values; (3) Community planning and water circularity create a self-sustained living unit in Kampung Naga. Findings from this study can improve our body of knowledge of potential solutions for future spatial development, where the relationship between human and water could be profoundly re-established.

Keywords

circular water stories, heritage landscape, Indonesia, Kampung Naga, landscape architecture

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Introduction

As one of crucial resources for life, water has always been a major influencing factor on humans when choosing a place to reside. Along with the development of the civilisation, people have manipulated its watercourse, function and form, to fulfil their essential needs (Hein et al., 2019). People and water are inseparable; their relationship influences the formation of living space and people's social and economic activities, as well as establishing an identity for society for hundreds or thousands of years.

In developing countries such as Indonesia, knowledge about the indigenous water systems are still maintained by some traditional societies, but little of that knowledge has been integrated into present-day spatial design and planning. High rates of population growth, rapid urbanisation, and lack of a comprehensive long-term regional planning results in a sprawling settlement. Missing connections between physical development and the existing surrounding nature accelerates environmental degradation. The spatial relationship between humans and water is often lost.

Water in the city is mostly polluted, closed, and disconnected from people's living space (Burkett, 2020). Knowledge of the heritagewater landscape could provide insightful solutions on how this spatial relationship could be redefined.

Kampung Naga shows a well-maintained habitat, where the community lives not only in nature, but with it. It is a traditional Sundanese hamlet in the rural area of Tasikmalaya in West Java, the most populated province in Indonesia (with 43 million people). Surrounded by hills and gifted with fertile soil, inhabitants of Kampung Naga run a living system based on a profound understanding of how the natural system works. The circular system in Kampung Naga has proved to successfully accommodate a self-sufficient community, still living to this day.

FIGURE 1 Kampung Naga from the main access.

Due to its distinctive traditional lifestyle, many articles have discussed Kampung Naga from diverse perspectives: heritage architectural design and traditional building technology (Sudarwani, 2016;

Khairunnisa, 2014; Utami, 2014; Darmayanti, 2018), Ethnography and Local Wisdom (Qodariah & Armiyati, 2013; Iskandar & Iskandar, 2018; Iryana, 2014; Prawiro, 2015), Agriculture and Environment Studies (As'ari & Hendriawan, 2016; Maria, Indrawati, & Astuti,1995), and water management system (As'ari et al., 2018; Wahadamaputera, Nauw, Sondaka, Ningrum,& Maulana,2014). However, studies on how the interaction of water, ecology, and social system shapes its spatial structure are given little attention. This shows that the water, space, and cultural heritage, although they are linked inseparably through complex interrelationships, are still approached as siloed perspectives (Hein et al., 2019). Thus, this article aims to fill this gap of knowledge.

Two main methods were adopted to collect and analyse data for this research. First, profound research on the existing literatures about Kampung Naga in water management, ecology, architecture, as well as culture and local wisdom. Second, field observation and interviews were conducted to get more empirical information on how these categories underlay the sustainable living created by inhabitants. Interviewees have various positions in the village, including the headof local organisation, the customary council, local tour guide, and some other male and female inhabitants to gain comprehensive understanding on the local wisdom, social and economic activities in the village. Both data sources then were processed to comprehend the main values held by the community which shape its heritage landscapes. Spatial drawings are presented to show the relation of water, ecology, and the social and economic circular system in spatial constructions.

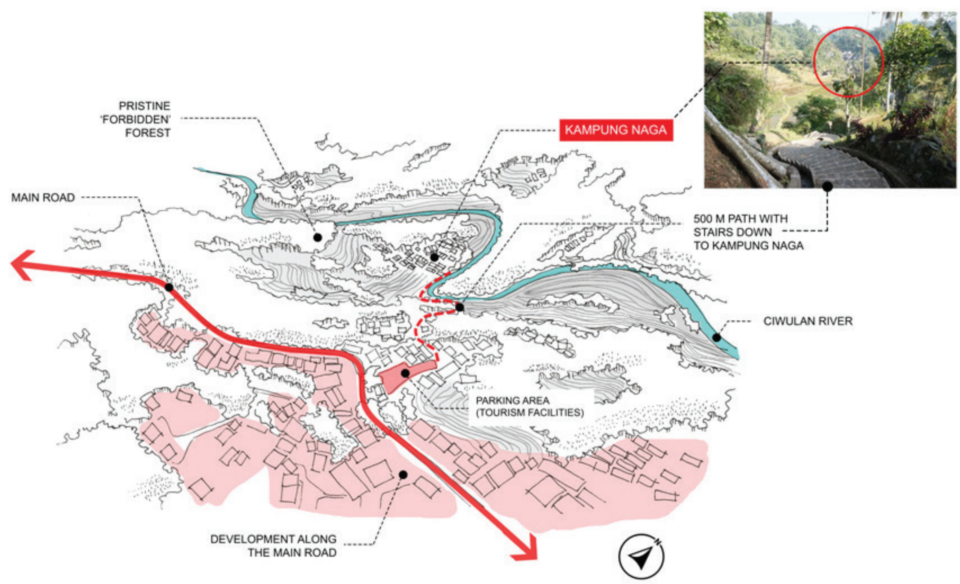

FIGURE 2 Location of Kampung Naga.

Landscape/ Place/ Order

Kampung Naga has inherited its own traditional way of life without intrusion of new culture or technology, although it is only a half kilometre away from the main road which connects two cities, Garut and Tasikmalaya (Sudarwani, 2016). The hamlet is located on the foot of the hill covered by dense forest on one side, which makes it invisible from the main road. A stone staircaseat a45 degree slope along the valley eventually brings visitors to a mesmerising vernacular settlement underneath the forest (Fig. 2).

Spatial strategy of Kampung Naga

The hamlet is located at the most strategic place in the composition of the existing landscape. A total of 1.5 hectares constitutes the living area of Kampung Naga, which comprises 112 traditional buildings (109 houses and 3 public buildings). It has 101 households with a total population of 297 people (Ucu, personal communication, 2019). The forbidden forest is preserved from any human activities on the hilly western side above the settlement. It absorbs rainwater and maintains the groundwater supply, and soothes strong winds and the westerly sun. The houses are located on a slope facing in an easterly direction, which receives more morning sunlight and makes it an ideal place both for residential and agricultural land (Darmayanti, 2018). According to Sudarwani (2016), water from the forest that has a lower temperature flows down into the settlement area, thus cooling and refreshing the warm air within the village.
Another eye-catching landscape is the oxbow of Ciwulan river, which wraps around Kampung Naga from the northern to the eastern side, covering almost half of its edge. As an agricultural community, Kampung Naga is heavily dependent on the water source of the Ciwulan River. These clear roles of the two landscape elements – forest and river – become natural buffer zones to prevent the expansion of the dwelling zone, while at the same time give a pleasant living environment for the native inhabitants (Fig. 3).

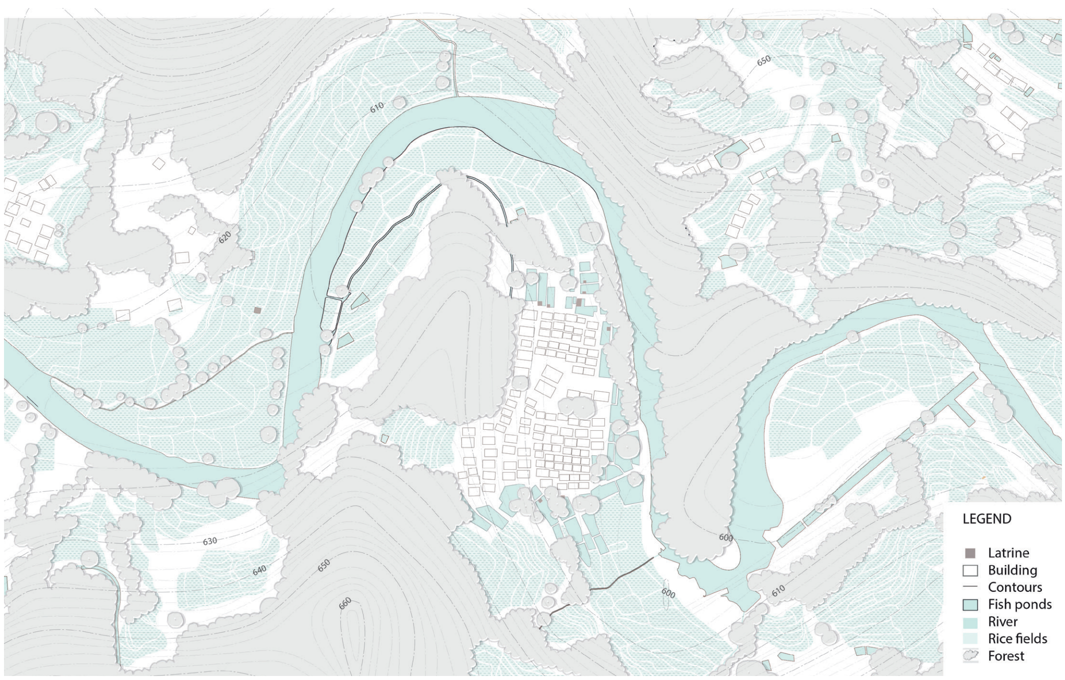

FIGURE 3 Plan of Kampung Naga.

Zoning on Topography

The hilly topography has been a strong influence in defining zones within the village. The village is divided into three zones that correspond to distinctive types of activities, which are integrated with the circular water system as the main support system of the inhabitants' lives. Many literatures describe the zones based on the sanctity of each zone, namely the sacred zone, the clean zone, and the dirty zone (Qodariah & Armiyanti, 2013; As'ari & Hendriawan, 2016; Sudarwani, 2016; Iskandar & Iskandar, 2018). In this paper, we name the zones based on how they relate spatially to the settlement area. The term 'Sacred area', which represents how people perceive the place, is still used to differentiate between the two zones outside the settlement area.

The Sacred area (*Leuweng Karamat*) is located at the highest altitude. It consists of a wildlife forest with strictly restricted accessibility. The roots of the trees play important roles in maintaining the soil structures and purifying the groundwater. Beneath the Sacred area, the Inner area comprises the houses and the main buildings of the village. The lowest part of the village is called the Outer area, positioned between the Inner area and the Ciwulan River. In this zone, all the water-related activities, from utilising to purifying, are carried out before it is discharged back to the river. Bamboo fences are used as the boundary of the settlement area, while simultaneously clearly separating these zones (Fig. 4).

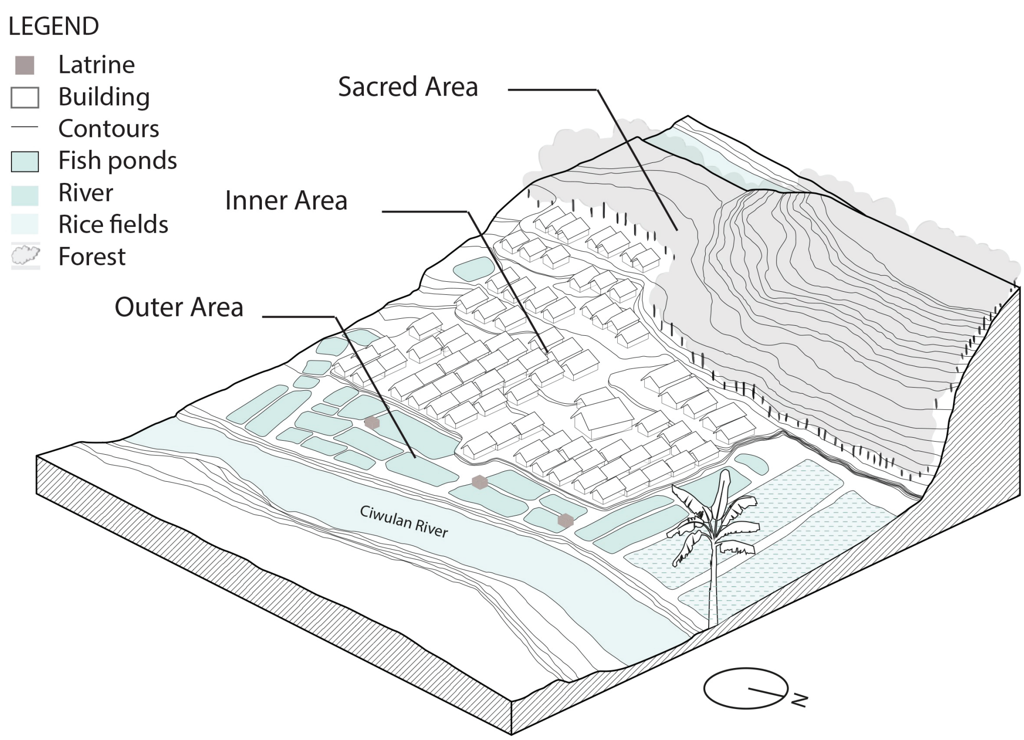

FIGURE 4 Zoning of Kampung Naga.

Pattern & Space

The neighbourhood in which houses positioned on the foothill creates harmonised linear arrays toward theriverside. When we look closer into the settlement pattern, the houses are arranged in a linear pattern parallel to the contour lines (Fig.5, left). Sudarwani (2016) mentioned that the house's dimensions are determined based on the specific dimension of the human anatomy and related to the day of birth of the house' occupants. Another factor that determines the length of the house is the width of the flat grounds (approx. 10m) which can be made from the natural topography (Ijad, personal interview, July 11, 2019). The various sizes of the houses do not represent the different social status of the occupants, as they believe all humanbeings to be fundamentally equal.

Another spatial strategy can be found in the arrangement of the houses, where they form a linear structure in which the houses are facing each other, with the buildings connecting at different ground levels (Fig. 5, middle). This corridor maximises natural ventilation and catches the prevailing breeze, creating a convenient microclimate in the village, especially during the rainy season (Darmayanti, 2018).

FIGURE 5 Composition of buildings. Left: linear pattern based on same elevation. Middle: linear pattern for wind direction and stormwater management. Right: public buildings located in the middle of the village.

On the other hand, the public square is centralised by location. It is used for any communal activities and social gatherings related to rituals and traditions which maintain the cohesive community atmosphere. The square is located in front of the main buildings, such as the mosque, community hall (*Bale Patemon*), the sacred building (*Bale Ageng*), and the main rice storage (*Leuit*), which form the centre of the village. This spatial composition imposes the importance of social gathering and control within the community.

FIGURE 6 Centralised and linear space inside the settlement.

Endless Flow of Water

The inhabitants of Kampung Naga believe that there is no such thing as a natural disaster. Rather, they believe that it is human activities that can bring about natural damage, which ultimately results in the losses that befall them. With this belief, water is treated as a major part of their lives. People allow the water space to 'breathe', use it wisely, and purify the wastewater before finally returning it to its original place. Contrasting with the urban water and wastewater infrastructure, which are invisible and inaudible (Burkett, 2020), water can always be seen here, and the sound of its flow can always be heard in almost all parts of the village. Its close connection to their living space affects the inhabitants' consciousness, motivating them to maintain its quality.

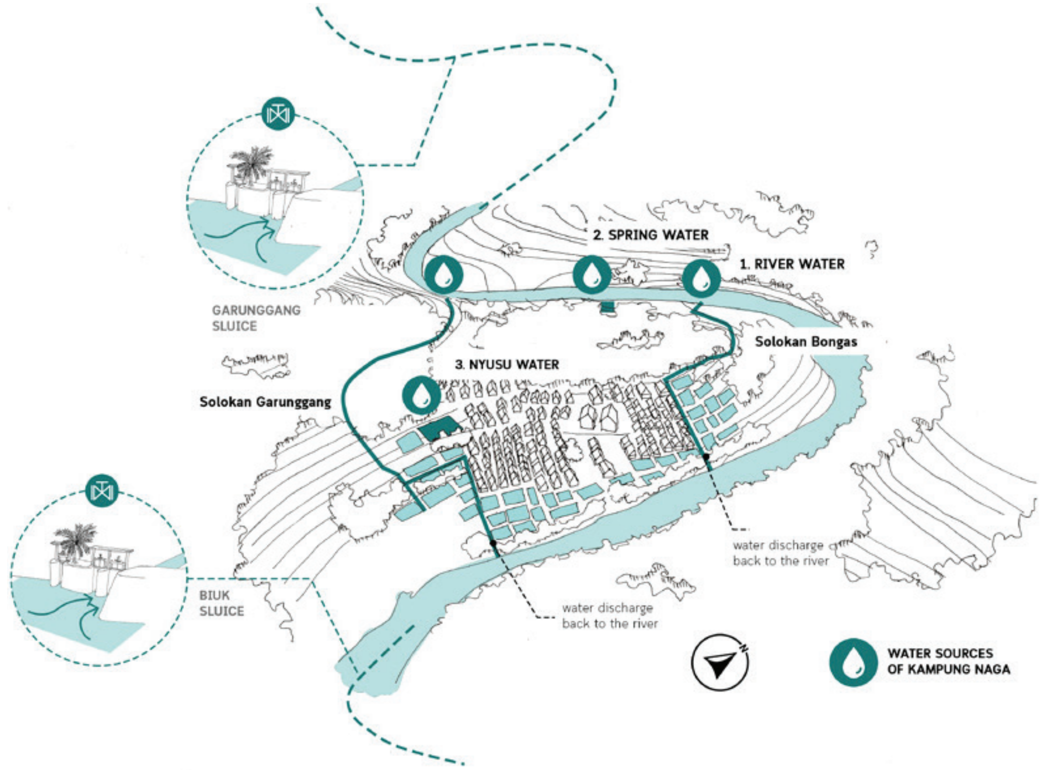

FIGURE 7 Water Sources of Kampung Naga.

Multiple Sources of Water

The inhabitants of Kampung Naga realise that besides the seasonal influences, human activities from the surrounding environment could affect the water quality. Thus, having more than one water source is crucial. Kampung Naga has three main water sources, the Ciwulan River, and two springs on the hills which people distinguish one to another (Spring Water & Nyusu Water) based on the consistency of its water quantity and quality. These three water sources are used for different functions for the inhabitants' daily lives. Ciwulan River flows upstream to Biuk Forest at Cikuray Mountain and downstream towards the Tasikmalaya regency, where it passes through Kampung Naga on its way. It does not pass through dense urban areas, thus avoiding a large amount of harmful pollutants. It flows constantly all year around, which makes it the main source of water for Kampung Naga. Two main sluices are used to regulate the river.

The Garunggang Sluice is located 3 km up from the village and the Biuk Sluice is located beneath, at the edge of the village area, where riverbank structures were also constructed as a long-term preventative measure against erosion. Water from Ciwulan River flows to the village through two channels, namely Solokan Bongas (Bongas channel) which runs on the northern side and Solokan Garunggang (Garunggang channel) which runs on the southern side (Fig. 7). Water discharge from the river to the village is regulated by using piles of rocks. Through these channels, water is filtered naturally by wild grasses and gravels, and is then distributed towards the agriculture area and water tubs at the latrines (Wahadamaputera et al., 2014) (Fig. 8).

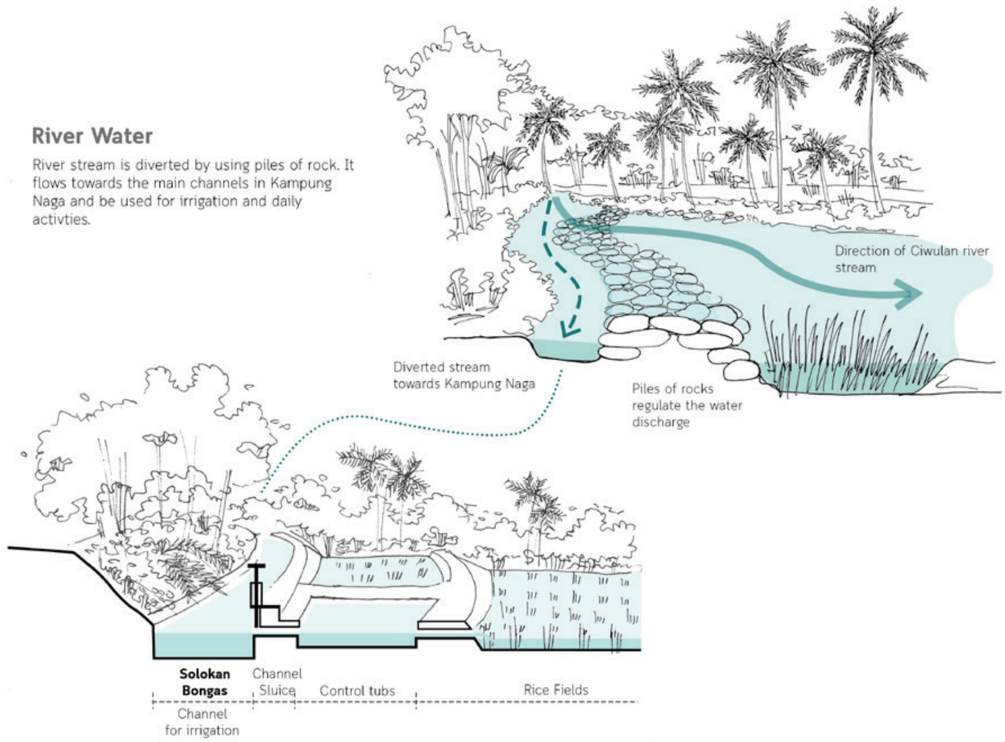

FIGURE 8 Source of Water - River Water.

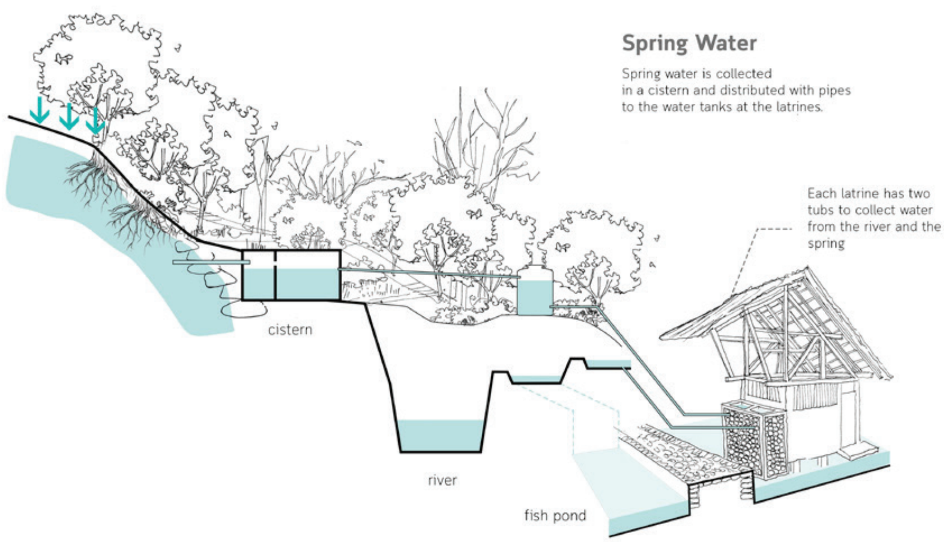

FIGURE 9 Source of Water - Spring Water.

An increase of water discharge during the rainy season influences the water quality of the river. Faster river currents cause mud to rise along the water stream, resulting in a murky river. This muddy water is also exacerbated by the ploughing activities during the rice planting season. During this season, river water is still used for agricultural activities, while water for bathing and washing activities is replaced by the spring water. The spring water is located behind the hill at the back of the village and channelled in two directions, to the mosque located at the centre of the village and to the Outer Area where the latrines are located.

With two kinds of water sources, each latrine has two separated cisterns to maintain the quality of the water (Fig. 9). Closer to the village, another spring (Nyusu Water) is utilised as a source of potable water. Nyusu water always has constant capacity and quality regardless of seasonal change. It is the result of water infiltration through the tree roots of the forbidden forest on the hill bordering the village on the western side. The community made an opening in the walls against the hill to allow the water to flow to the faucets located at a large pond underneath in order to ease the water uptake for daily consumption (Fig. 10).

In the Inner area, water can only be accessed through a station close to the mosque. It is used for cleaning rituals before praying activities, and occasionally used when the community washes their food materials. Almost all water-related activities take placein the Outer area, consisting of the latrines, fish ponds, and washing area, all of which are located at the lowest elevation. A system of ditches, pipes, and control tubs are used to distribute the water following its natural topography.

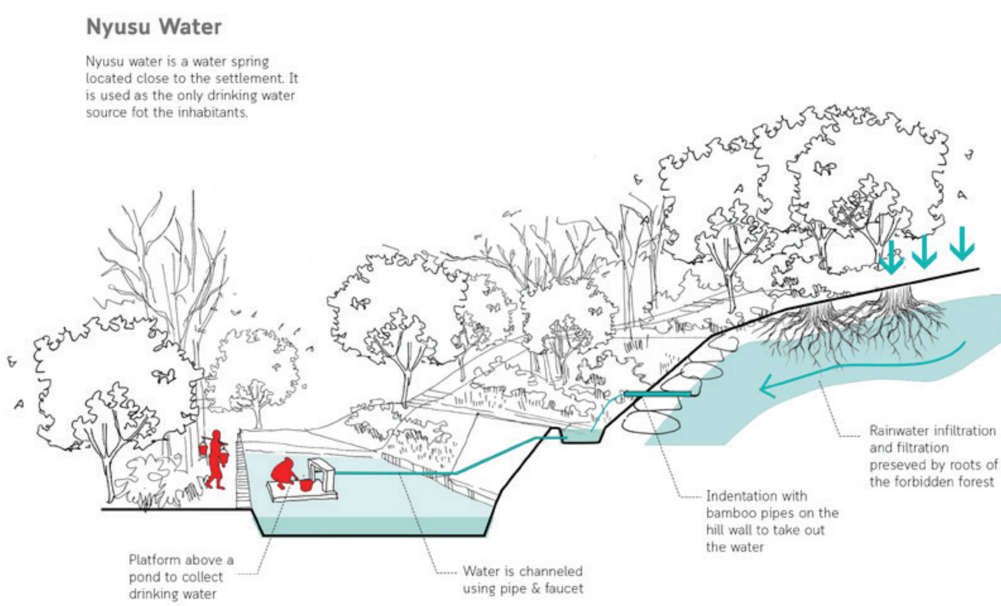

FIGURE 10 Source of Water - Spring Water (Nyusu Water).

At the agricultural area, each plot of the rice fields is bordered with small embankments and ordered as a terracing system following its natural contours. The water is distributed by gravitational force from the top to the lowest plot of the rice fields (Fig.11). While all privately-owned fields are connected to each other, there is no formal organisation applied in the management of water for irrigation. Hence, the inhabitants apply designated rules about the maximum pipe size to irrigate the rice field only to share the water resource equally by maintaining their customs. A manual system to open and close the bamboo-made water conduits, allowing control of water to flow to each parcel even with diverse planting times.

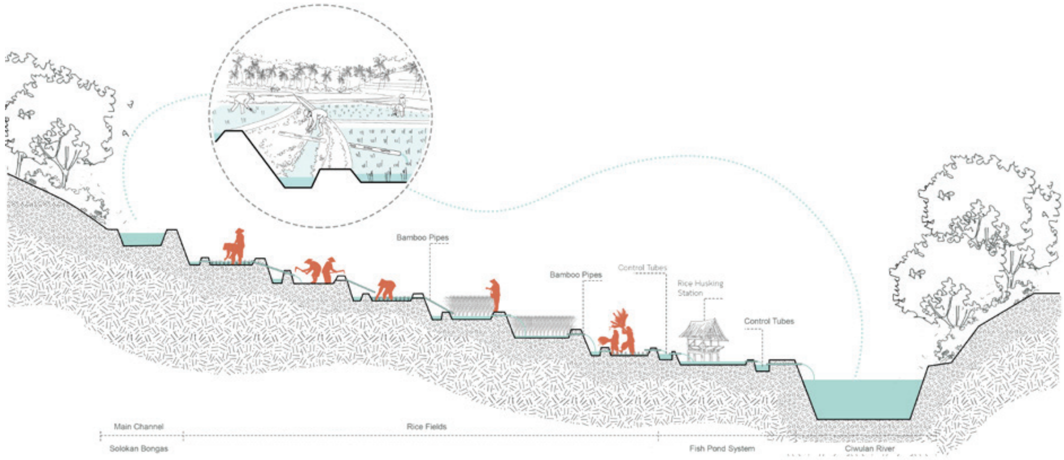

FIGURE 11 Water System in the Terraced Rice Fields.

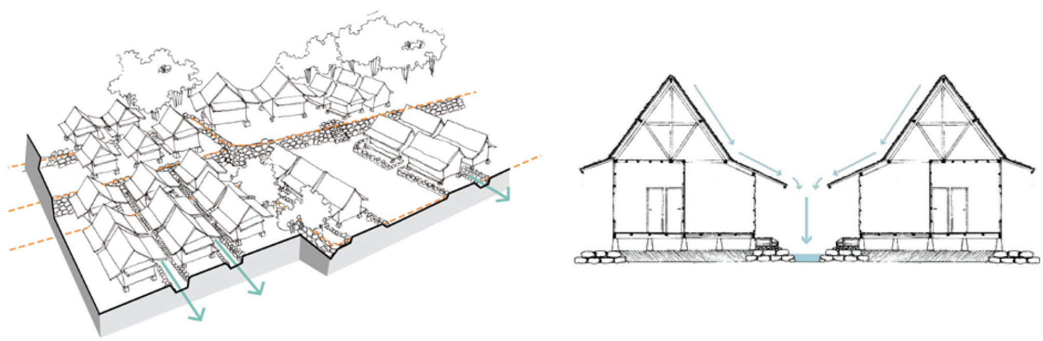

FIGURE 12 Left: Linear pattern of the houses forming storm water drainage system. Right: Stone podium of the two houses create space to collect and to drain the stormwater. Original image by NanneKnijff (redrawn).

Stormwater and Wastewater Management

Rainwater is well infiltrated in Kampung Naga by maintaining minimum use of pavements inside the village. Only the main access pavement is made of stone, while the other access routes between the houses and the open spaces are made of compacted soils. The stone structures, which have no adhesive materials, are also used as retaining walls which are aligned with the hilly topography. This allows water to penetrate through the thin gaps between the stones. Houses are organised in rows to form corridors where the tips of the roofs meet on lines (Fig. 12 - Left).

Within this arrangement, rainwater is collected in the ordered gravel ditch lanes. To anticipate long standing water when rainwater discharge increases, rows of gutters traverse the contours from the higher to the lower area to the main drainage system that connects to the river. In support of this solution, each house is designed to stand above a stone podium which also functions as the border of the gutter (Fig. 12 - Right). Moreover, the system that reduces the formation of standing water controls the growth of mosquitoes.

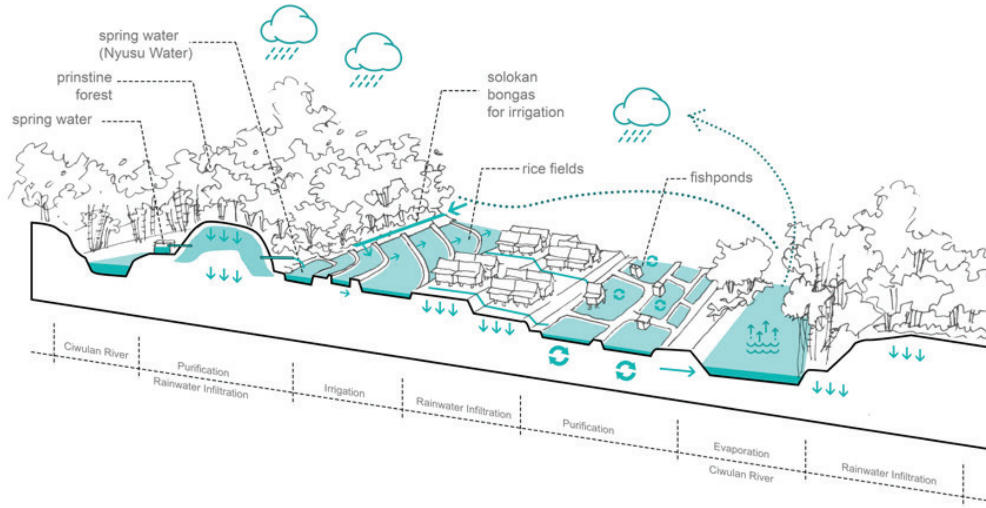

FIGURE 13 Water Circularity in Kampung Naga.

The management of household wastewater has been regulated, starting from the utilisation of the topographical zoning system (Fig. 13). Located at the lowest zone, the wastewater from the public bathrooms will not contaminate the living space. Wastewater flows directly from the latrine to the fishponds underneath. These fishponds have multiple functions: they are a place to raise fish as one of the food resources for the community, while at the same time naturally filtering the water from human waste. Purified water flows through a drainage system with control tubs between the fishponds towards the river.

Compacted clay was originally used to construct the pond walls. It was formed using bamboo slats as shuttering until the clay structures are dry enough to be stable. The main gutter, pond walls, and control tubs are currently stone and concrete structures. The centralised position for the public interest is also applied in the fishpond system. The largest pond, located in the centre, is owned by the village, and is used for raising fish which can only be harvested for public consumption during special events, while the surrounding fishponds are mostly owned privately by the inhabitants.

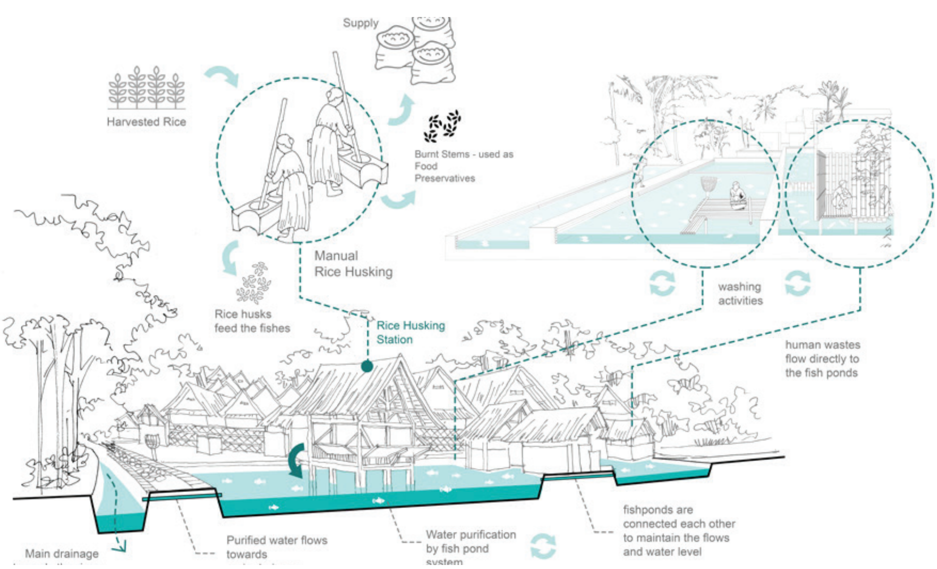

FIGURE 14 Ecological Circularity in Kampung Naga.

Ecological Circularity: No Wasted Resources

Kampung Naga successfully maintains the cycles of their multiple natural resources. These efforts are reflected in the spaces that have been created as a part of their environment, for example, the optimal use of rice crops. Rice husking stations are built above the fishponds. In these stations, rice is manually pounded to separate the grain from the outer husk. The husks are thrown into the pond to feed the fish, which eventually become a source of food for the community. In addition, the stems are collected and burned to be used as natural shampoo, cure some skin diseases, and are also used as a natural preservative for certain foods (Fig. 14).

Another example of the circularity can be seen in the architectural design of the house. The house is raised on stone pedestals to protect the wood structures from termites, which come from the humid ground. The space under the house is used to store firewood and raise chickens, which also act as a natural control against the termites. A floor made of bamboo slats floor is used in the kitchen area to allow the ash from the traditional stove to fall down through its fine gaps. This then mixes naturally with the chicken faces underneath. Within 3-6 months, this mixture will form natural fertilizer for the community's crop. Wood from the fields is collected for cooking and building materials (Fig. 15). With these circular processes, people can fulfil their basic needs within the village from nature.

Kampung Life: Faith And Social Bond

The inhabitants of Kampung Naga preserve the traditional way of living. There is no new technology such as electricity, modern agricultural equipment,and any form of foreign intervention, which does not conform with the values of their culture, is disallowed in the hamlet. This conservative mindset is strictly taught through social regulation, social involvement, and belief, which are deeply rooted in their myth and philosophy.

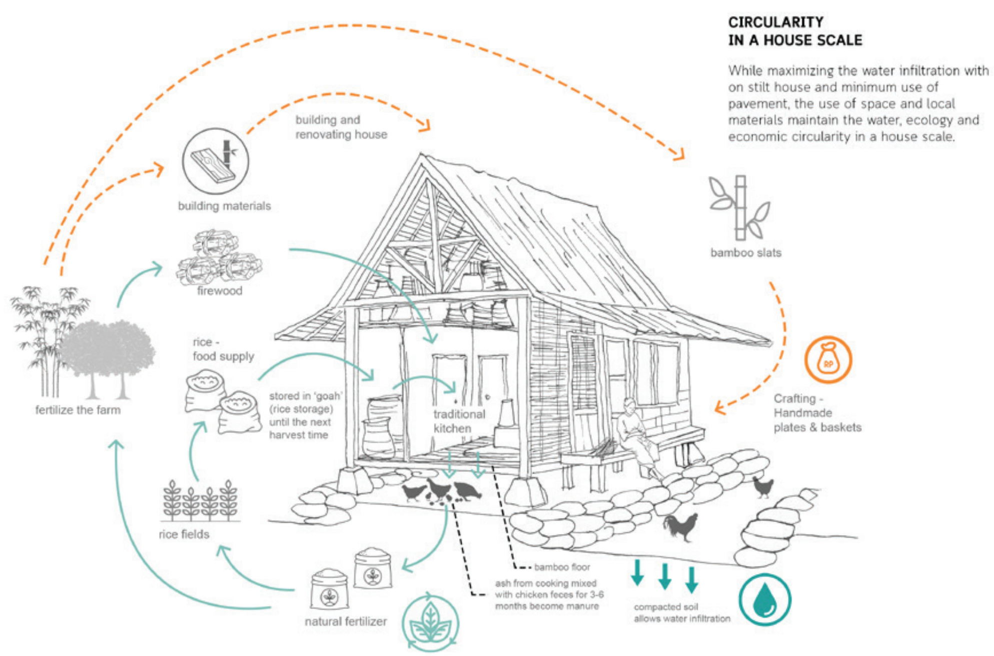

FIGURE 15 Ecological Circularity on a house scale.

Rules and Restrictions for Environmental Management

A circular ecology and water system might be difficult to maintain if inhabitants do not retain their tradition regarding their sustainable way of living. Besides the logical thinking of using the natural topography, the three zones in Kampung Naga represent their view as a Sundanese traditional community of the cosmological concept called Tritangtu, a trinity that they believe is required to be balanced in order to live harmoniously (Darmayanti, 2018). This concept may be applied into the vertical spatial hierarchy of the traditional house, as well as the zoning system in Kampung Naga (Darmayanti, 2018). The three vertical spaces represent the world in Sundanese culture, comprising Upper world (*BuanaNyungcung*):

- a sacred place for the ancestor and holy spirits; Middle world (*BuanaPanca Tengah*)
- a living place for all the houses and the main public buildings such as the mosque, community hall (*Bale Petemon*), a public granary (*leuit*) and the sacred house (*Bale Ageng*);
- and Underworld (*BuanaLarang*) where the fishponds, fields, rice fields, and rice husking station (*SaungLisung*) are located (Darmayanti, 2018).

Based on this cosmological world frame, circular living is controlled and passed down for centuries by spatial boundary, social education, and communal events.

There are lots of verbally stipulated customary restrictions and rules which are inherited and preserved to maintain the structure of the community (As'ari & Hendriawan, 2016). This is also elaborated into single details on how community members should live with nature, including space orientations, the wisdom in using the water, building construction techniques, and the utilisation of local materials. Through myth, ritual ceremonies, and direct visualisation of the concept in spatial constructions, three educators - a customary leader (kuncen), family, and community - strengthen each other in passing down the values of the tradition. This becomes the pattern of thought and is transformed into an integral part of daily life at Kampung Naga (Iryana, 2014).

The biophilic mindset to conserve their environment are taught along the faith that violation of this tradition would bring negative impacts for the community's life. One of the examples is that the forbidden forest can only be visited by men during the ritual ceremony because this forest is home to the spirits (Iryana, 2014). With this restriction, the forbidden forest is preserved with no human disturbance. These well-observed provisions end up enriching the ecosystem's services. Its rich ecosystem provides local people with literally everything to live, such as food, medicine, and plant-based building materials – bamboo, palms leaves, etc. People create tools they need and build the house from scratch. They weave handmade plates, baskets, and other items from bamboo. As complemented by the resources that could be gained from agricultural activities, people are entirely self-sufficient.

Craftsmanship as a Tool for Social Bond

While the community expands beyond the traditional village, craftsmanship in functional elements persists and is utilised as a tool to keep a strong social bond between the community members who live both inside and outside the village. For instance, the village border is marked by bamboo fences which must be changed every year. The job of replacing the fences is not a hassle for the community, but a good chance to invite their relatives to join in. Another example is the decision to keep using piles of rocks to regulate the river water discharge instead of changing it to concrete structures; the activity of maintaining the rocks requires that people work together so that they build up the community spirit. It is another reason for using manpower, craftsmanship, and choosing natural materials over modern technology to maintain Kampung Naga.

Limits & Challenges: When We Think About Applying To The Urban Context

Kampung Naga is one of the idealistic examples on how a community lives in balance with nature. It is formed as an independent self-sustained community with sets of rules and restrictions preserved by the community both in developing their living space and maintaining the ecological circularity of its environments. However, Indonesia as a developing country with rising issues such as a high rate of population growth, rapid urbanisation, and lack of comprehensive long-term regional planning, could challenge the sustainability of this balanced life, as well as the possibility for the application of the values and local wisdom to other places in the future.

The Strict Settlement Boundaries

For hundreds of years, Kampung Naga has preserved the boundaries of its settlement area. The inhabitants can make new families and increase the number of their family members, but it is strictly forbidden to expand the living space inside the village. In this situation, Kampung Naga could maintain around 297 inhabitants (with a maximum of 320 inhabitants) living inside the village Ijad, personal interview, July 11, 2019), while the rest of the family members could live outside the traditional village (Iryana, 2014). By adhering to these rules, it is possible for Kampung Naga to maintain the correct balance between the community size, agricultural area as a main source of food supply, as well as its capacity to regulate the water cycle. However, with a highway - one of the determinants of urban sprawl (Firman, 2008; Mulyana, 2014) - located close to the village and its current state as a cultural tourism site, Kampung Naga is facing the challenge that natural boundaries might shrink due to the overwhelming growth of the surrounding population. It would be difficult to argue their right to maintain the strict boundary and consequently they may be forced to open the gate, contrary to their custom of population control within the village. On the other hand, applying a similar system in the urban realm is not seemingly logical population management, as people can move freely. When urbanisation increases, problems follow: limited space and high demand on resources for an increased number of dwellers might occur.


FIGURE 16 Left: Bamboo fences separate each zone in Kampung Naga. Right: Handcraft using bamboo slats.

The Refusal of New Technology and Development

Kampung Naga's community believes that conservatism toward new technology is necessary to maintain the purity of their culture and tradition. Once technology is utilised, almighty nature can fade under the shade of technology (Prawiro, 2015). Unlike Kampung Naga, where fishponds take up more space than residential areas, due to the large capacity of water needed for self-purification, crowded urban areas need a more advanced system for higher density, although its side effects could also degrade nature. A city is highly controlled, preventing nature from working fully within its limitless power. The co-existence of nature and applied science is one of the biggest challenges that inspires people to have a biophilic attitude.

Closed Community and Customs

Despite following Indonesia's administrative leadership structure, Kampung Naga also has a customary council leader (kuncen) who takes charge of the rules of tradition under Islamic culture (Maria, Indrawati, &Astuti,1995). Any inhabitants who violate rules will get an appropriate punishment, the worst of which is to be exiled from the community. To apply a similar system in an urban setting could be problematic. Many cities consist of mixed cultures, religions, and customs,allowing people to live more freely by individual choice. Thus, a tight-knit community sharing the same values could lead to segregation within a broader multi-cultural society.

Governing Coalition for Sustainability

A regional development plan could be a potential plausible actuality. Kampung Naga is considered to be a self-sufficient unit, but it cannot hinder its connection to other surrounding areas, even beyond the natural boundaries. The government's decision on a new regional development plan is capable of changing land use directly and indirectly. This could be easily understood by referring to the water issue, a crucial resource for living. It is the continuous resource that flows from the Mountain Cikuray through other upstream villages along the contours and reaches Kampung Naga. Once water infrastructures (dams and irrigation systems) are developed, both inhabitants' agricultural activity and the ecosystem can be badly affected. In other words, change of land use in the adjacentarea will greatly influence the water quality and ecosystem in Kampung Naga. Thus, domestic water treatment for the river will be indispensable in the future.

In the agricultural system, the use of fertilizers is slowly affecting the quality of the river water that comes out of the village. On the scale of the village, this challenge can be controlled by the restriction of fertilizer use for the crops. However, the threats regarding the river water quality could still come from neighbouring villages located upstream along the river. It is crucial to come to a mutual understanding on keeping the river free from any industrial activities which could pollute the water. Without such an agreement on managing the river at a larger scale, this would always be a potential threat that could greatly impact the lives in Kampung Naga.

Furthermore, governance cooperation is not confined to the national scale. On a global scale, climate change means that nature might not be able to function as effectively as it is currently. Since the life of Kampung Naga depends entirely on ecosystem services, the community would be threatened by any damage to its living support system. This assumption applies equally to complex urban areas, if we adopt this self-supporting system. It would be appealing to create a more compact circular ecosystem through the intervention of technology to maintain a balance of supply and demand chains.

Conclusions

From the research, three lessons can be learned from the water heritage system of Kampung Naga:

- Understanding how the natural landscape works is crucial in determining spatial development. The integration offers people benefits of living with nature and maintaining it over a long-term period. Kampung Naga utilises existing topography to designate the orientation of the houses, the clear zoning plan of the settlement, water related amenities, agriculture, and wildlife.
- A circular water system is elaborated based on the natural landscape and ecosystem service. Local people explicitly understand the natural characteristics needed to utilise multiple water resources, as well as their responsibilities to purify the wastewater before discarding it back to the river. However, this circular metabolism could only be maintained by integrating it into its cultural, social, and economical values for the local inhabitants.
- Community planning and water circularity create Kampung Naga as a self-sustained living unit. Strong cultural identity drives inhabitants to maintain self-sufficient food production and ecological cycle by limiting the development area. This control is held by faith and traditions which are preserved by the inhabitants in their daily lives.

All in all, we could understand the heritage water landscape through learning how the interactions between landform, water, ecology, and anthropology create the entire system. It influences how people create spaces to live and establish some restrictions to maintain its sustainability. Understanding the heritage landscape might not offer immediate solutions to current water problems on a global scale. However, it could improve our body of knowledge of possible solutions of future spatial development, where the relation between humans and water could be profoundly re-established.

References

As'ari, R & Hendriawan, N. (2016). *Kajian Nilai Kearifan Lokal Masyarakat Adat Kampung Naga dalam Pengelolaan Lingkungan Berbasis Mitigasi Bencana [Study of the Values of Local Wisdom of Kampung Naga's Indigenous People in the Environmental Management based on Disaster Mitigation].* Prosiding Seminar NasionalGeografi UMS 2016. ISBN: 978-602-361-044-0

As'ari, R., Rohmat, D., Maryani, E., & Ningrum, E. (2019). Management of water resources based on local wisdom: a development study of Kampung Naga as a field laboratory of Geography Education in Tasikmalaya, West Java. In *IOP Conference Series: Earth and Environmental Science* (Vol. 243, No. 1, p. 012002). IOP Publishing.

As'ari, R., Sari, W., & Meilani, D. (2018). Pelestarian Sungai Ciwulan Berbasis Kearifan Lokal Leuweung Larangan di Kampung Adat Naga Kabupaten Tasikmalaya [Conservation of Ciwulan River based on the Local Wisdom Leuweng Larangan in Traditional Kampung Naga, Tasikmalaya Regency]. *Prosiding Seminar Nasional Geografi UMS IX 2018*.

Burkett, M.H. (2020). Silent and Unseen: Stewardship of Water Infrastructural Heritage. In C. Hein (Ed.), *Adaptive Strategies for Water Heritage* (pp. 21-37). Retrieved from: https://doi.org/10.1007/978-3- 030-00268-8_2

Darmayanti, T. E. (2018). Sundanese Traditional Houses in Kampung Naga, West Java as Part of Indonesian Cultural Tourism. *Journal of Tourism*, 3(8), 57-65.

Firman, T. (2008). *The Patterns of Indonesia's Urbanisation, 1980-2007.* Population Association of America, 2008.

Hein, C., van Schaik, H., Six, D., Mager, T., Kolen, J., Ertsen, M., Nijhuis, S, & Verschuure-Stuip, G. (2020). Introduction: Connecting Water and Heritage for the Future. In C. Hein (Ed.) *Adaptive Strategies for Water Heritage* (pp. 1-18). Cham: Springer. https://doi.org/10.1007/978-3-030-00268-8_1

Iryana, W. (2014). The Mythology of Kampung Naga Community. *Al-Albab*, 3(2).

Iskandar, J. & Iskandar, B. S. (2018). Etnoekologi, Biodiversitas Padi dan Modernisasi Budidaya Padi: Studi Kasus Pada Masyarakat Baduy dan Kampung Naga [Ethnoecology, Rice Biodiversiity and Modernisation of Rice Cultivation: A Case Study of the Baduy and Kampung Naga Communities]. *Jurnal Biodjati*, 3(1), 47-62.

Khairunnisa, M. (2014). Kosmologi Ruang Adat Sebagai Identitas Pemukiman Kampung Naga, Tasikmalaya-Jawa Barat [The Cosmology of Costumary Spaces as the Identity of the Settlement in Kampung Naga- West Java]. *Teknik*, 35(1), 49-55.

Maria, S., Indrawati, D., & Astuti, R. (1995). *Sistem Keyakinan pada Masyarakat Kampung Naga dalam Mengelola Lingkungan Hidup (Studi tentang Pantangan dan Larangan) [The Belief System of the People of Kampung Naga in Managing the Environment (A Study of Taboo & Prohibition)]*. Direktorat Jenderal Kebudayaan

Mulyana W. (2014). Rural-Urban Linkages: Indonesia Case Study. Working Paper Series N° 126. Working Group: Development with Territorial Cohesion. *Territorial Cohesion for Development Program.* Rimisp, Santiago, Chile.

Prawiro, A. M. B. (2015). Religion and the Local Tradition of Life Cycle Rituals in Kampung Naga, West Java. *Al-Albab*, 4(1), 55-68.

Qodariah, L., & Armiyati, L. (2013). Nilai-Nilai Kearifan Lokal Masyarakat Adat Kampung Naga sebagai Alternatif Sumber Belajar [The Values of Local Wisdoms of the Indigenous Community of Kampung Naga as an Alternative Source of Study]. SOCIA: *JurnalIlmu-IlmuSosial,* 10(1), 10-20.

Sudarwandi, M. M. (2016). A Study on House Pattern of Kampung Naga in Tasikmalaya, Indonesia. *International Journal of Technology Enhancements and Emerging Engineering Research*, 4(58), 2347- 4289.

Utami, M. N., Ardi, F., Wildan, M., Saputro, A. D., & Utari, R. R. A. (2014). Kajian Sustainable Material Bambu, Batu, Ijuk dan Kayu pada Bangunan Rumah Adat Kampung Naga [Study of Sustainable Material of Bamboo, Stone, Palm Fiber and Wood in the Traditional House of Kampung Naga]. *REKA KARSA*, 2(2).

Wahadamaputera, S., Nauw, M. M., Sondaka, A., Ningrum, E. K., & Maulana, C. A. (2014). Pengolahan dan Pemanfaatan Elemen Air Sebagai Kearifan Lokal pada Arsitektur Kampung Naga [The Management and Utilisation of Water Elements as a Local Wisdom in the Architecture of Kampung Naga]. *REKA KARSA*, 2(3).

Mapping the Maritime Backyards of Póvoa de Varzim

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Abstract

In order to improve their professional activity, fishermen have developed special methods and procedures for organising the space of their maritime territory. This article presents some of these practices, based on the specific case of the fishing community of Póvoa de Varzim, a town on the north coast of Portugal. Over the years, each fishing family has developed mental maps of the "seas", creating original names to identify certain places and their different characteristics, while simultaneously producing a remarkable intangible heritage. Together with the productive transformations that were characteristic of industrialisation, traditional fishing methods have also gradually changed, incorporating the use of electronic navigation devices and other mechanisms for the detection of marine resources. In this way, the sea has begun to be mapped digitally through a system of "maritime backyards" that divide the space according to the fishing gear used. The aim of this work is to map and compare the maritime space produced by traditional fishing methods and by the contemporary system of "maritime backyards", giving visibility to practices and territories that are normally absent from the representations of places.

Keywords

maritime territory, fishing community, Póvoa de Varzim, intangible heritage, mental maps, "maritime backyards", map.

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Introduction

This article is an offshoot of the Fishing Architecture research project, whose aim is to map the complex relationships between marine biology and the built environment that results from the exploitation of natural resources such as fish and seaweed, which were fundamental vectors in the urbanisation of coastal towns and cities. The underlying hypothesis suggests that, from the integrated study and reading of the human activities involved in the exploitation of marine resources, new perspectives may emerge for understanding the history of the urbanisation and construction of the terrestrial landscape. As such, this research[1] study examines the fishing community of Póvoa de Varzim and its particular system for organising the space known as "maritime backyards".

The word "backyard" is normally associated with a plot of land (a vegetable patch, a patio, or a garden) at the back of a house. What meanings are therefore attributed to the word when used in the context of the maritime landscape? There is a common view of the sea as a mere line on the horizon and of the coast as a line that separates two territories, very often regarded as independent from one another. The land has been studied in depth by the disciplinary field of architecture, yet what exists beneath the sea's surface remains a "silent world"[2], one which is gradually becoming better known in the field of biology and in other marine sciences (Mustain, 2011). In architecture (urbanism and landscape), the sea is still portrayed in a fairly inexplicit way. To understand the continuity of sea and shore through this system, we need to use sources and records (such as nautical or hydrographic charts for example) and incorporate this information with the fundamental, precise, and sensitive accounts of those who live from and appropriate the sea: the fishermen, creating one common cartography.

After the chapter "*Methods and Materials*", this article is divided into two main chapters: firstly, the "*Póvoa de Varzim: The traditional fishing sea space method*" that explains the historical and cultural context and the first space method called "seas" created by this fishing community, ending with the sub-chapter "*The creation of a "sea"' in memory of the Master "Espojeiro*" representing the personal experience process of a new "sea" by this ex-fisherman.

FIGURE 1 Photographic record of the conversations with Master "Espojeiro" about traditional fishing.

1 This work is largely based on the Master's Degree thesis presented by José Pedro Fernandes, *Mapeamento dos quintais marítimos na Póvoa de Varzim,* School of Architecture, University of Minho, 2020, and supervised by Marta Juan Labastida.

2 *Le monde du silence* is the title of a documentary made by Jacques Cousteau and Louis Malle in 1956. It was one of the first documentaries to include underwater colour images. Besides winning the Palme d'Or at the Cannes film festival, it was also awarded an Oscar by the Hollywood Academy.

Methods and Materials

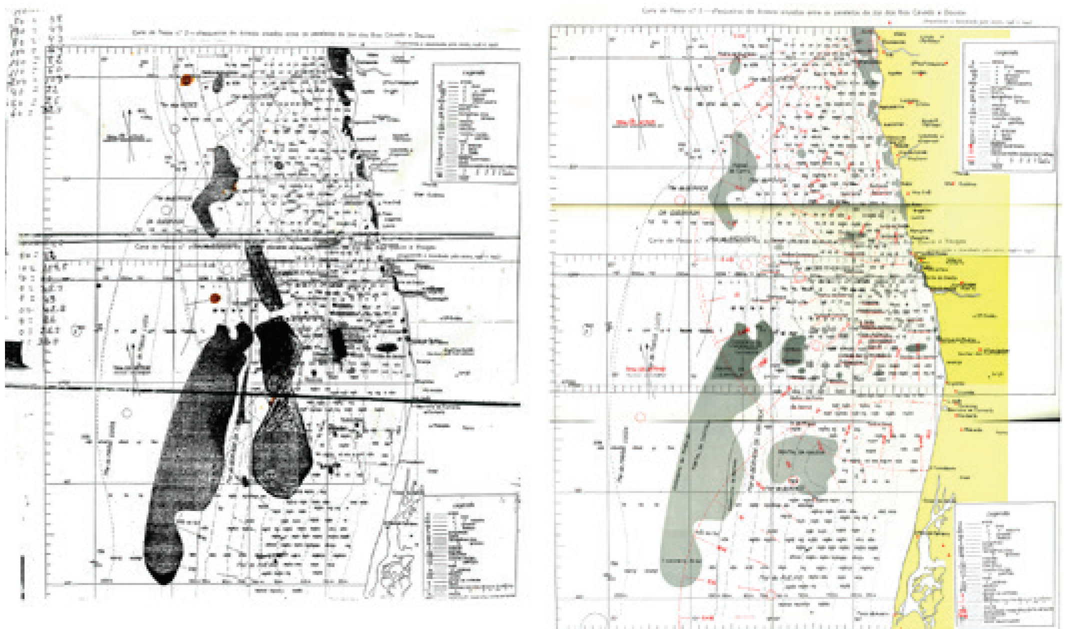

FIGURE 2 Transformation of the morphology of the maritime territory through Master “Espojeiro’s” notes between 1970 and 1990. On the left, a photocopy of the map of the trawling fishing grounds between the Cávado and Douro rivers, drawn up by Joaquim Gormicho Boavida (1948 edition); on the right, the original map.

In the last chapter, “*Póvoa de Varzim: The contemporary fishing sea space method*”, we pretend to explain the reasons of adaption for the actual space method called “maritime backyards”. Then, in the sub-chapter “*The architects of the sea*”, we explain the characteristics of this maritime space system organised by the polyvalent fishing community. And finally, the sub-chapter “*The creation and exploitation of a “maritime backyard*” represents the personal experience of José Fernandes with a polyvalent fishing crew and his “maritime backyards” system with all of its related process.

The expression “maritime backyards” has given rise to a series of questions relating to their origin and their morphology, as well as to their relationship with the tools of fishing and representation of the space associated with them. The intent is to explore the fishermen’s capacity for organising the maritime space through their professional activity. To better understand this space method, we decided to compose a series of drawings that could help us to visualise and locate their features and dimensions. And, in order to show the relationship between this construction and the evolution of the tools that were used, a comparison is made between traditional (artisanal) fishing and contemporary (polyvalent) fishing – two clearly distinct models that coexisted in this community in the latter half of the twentieth century.

In the first part, the research process is described and followed in drawings, using mental maps of the “seas” and the toponyms created and transmitted under the scope of traditional fishing. We compare documentary and bibliographical sources (cultural newsletters showing the evolution of the local heritage) with the memories of ex-fishermen. The article by Luís Martins (1999) gathers information from this community’s routines, tools, and social structure, which were previously described in the book of Santos Graça (1932).

In order to be able to transcribe this information into credible maps, it was necessary to clarify a number of questions and doubts with the details that only fishermen themselves can provide. We were able to talk to Master Albano “Espojeiro” (Fig. 1), an ex-fisherman from the last generation of the traditional fishing community of Póvoa de Varzim. Over the course of three meetings with him, Master “Espojeiro” shared with us his personal knowledge, notes, and maps, and it was from this information that we were able to reconstruct and represent the processes involved in the creation of the mental map of the “seas”. The most difficult part was to translate his description of the routines into actual physical dimensions, which

sometimes made it necessary to use different scales of representation on the same map. The information that we successfully collected from the various conversations was contrasted with that which was already available in other documents existing about these practices in Póvoa de Varzim at the Municipal Library.
In order to assemble our maps, we used the cartography from Gormicho Boavida (1948)[3] as the basis for the drawings of the first part, which Master "Espojeiro" himself had used for noting and correcting the changes that had occurred in accordance with his practical knowledge (Fig. 2).

The second part of the article begins with a discussion of the transition to contemporary fishing practices, associated with a paradigm of the global economic pressures, as the article by Luís Martins (1999) shows. There are a number of questions that arise globally, relating to: State or regional conservation policies (Matthews, 1993); the public or private domain of the maritime space (Lueck, 1993); the destruction of ecosystems (McGoodwin, 1989); but also the social transformations taking place in the fishing communities themselves, as in the case of Malaysia (Firth, 1975), the raftsmen of north-east Brazil (Forman, 1970), and the north-west of Newfoundland (Sinclar, 1985), among others. Particularly interesting in this article are the specific changes that took place in the fishing community of Póvoa de Varzim, which permitted the appearance of a new and unique system of spatial organisation: the "maritime backyards". In order to understand the functioning and morphology of this system for the occupation of the sea, we first had to confront an obstacle associated with its informal condition: there are no graphical or written records. Once again, it was necessary to understand the routines of the fishermen and the construction of their "maritime backyards". We had the opportunity to accompany a fishing vessel from Póvoa de Varzim over a period of six days. A master and shipowner agreed to explain the construction of his "maritime backyards", maintaining his anonymity, as well as that of his crew. The master provided us with his explanations on the boat itself, allowing us to take drawings and a photographic and audio-visual record. This experience further enabled us to understand the functioning of polyvalent fishing practices, as well as the tools and techniques that were used. This information made it possible for us to produce the original cartography of the "maritime backyards". In order to assemble the maps, we used the most recent cartography about the types of seabeds to be found in Póvoa de Varzim (*Carta da Serie*, 2017). In this way, it was possible to arrive at a series of drawings that summarised and explained the standard space of this system, resorting to the only credible existing information: the practical knowledge of the master (Fig. 3).

FIGURE 3 Polyvalent fishermen from Póvoa de Varzim fishing in their "maritime backyard".

3 Cartography subsidised between 1947/48 by the Guild of Trawler Owners, containing information about the types of seabed and the best fishing grounds (coordinates of fishing points). The aim was to create a guide that would show the hidden/submerged educational culture that this professsion had, and to express the intangible heritage that was worked upon daily through the interpretation and knowledge of the national maritime territory.

Póvoa de Varzim: The Traditional Fishing Sea Space Method

In this chapter, we were able to understand the importance of the *Poveiros*[4] and some of its specificities, which, after being compared with the detailed knowledge provided by Mestre "Espojeiro", helped to explain the process of mapping their routines and different ways of dividing the sea in a much more understandable and rigorous way.

In 1308, at the time when Póvoa de Varzim was beginning to acquire its administrative shape, activity was characterised by the complementarity between agriculture and fishing, including the harvesting of *sargasso*[5] (Amorim, 2004, p. 35). The fishing community was set up "on the fringes of the other land-based classes, since they had the privilege of having their own laws, habits, customs and traditions" (Cadilhe, 1977, pp. 157-173). The community was divided into "castes", organised according to family ties and bonds of consanguinity[6]. At sea and in their fishing activity, each family distinguished themselves from the others through their working tools, namely the handmade depth probes, the marker buoys, and the marking of the boats themselves. These working tools were the main link between the "seas" and the land, as well as the main material inheritance of each family.

Just like most fishermen on the Atlantic coast of the Iberian Peninsula, the *poveiro* moved, on a seasonal basis, from Galicia to the River Tagus in search of work (Areias, 1977, pp. 157-173), which enabled them to extend their knowledge of fishing techniques, maritime dynamics, and marine species (Cadilhe, *op. cit.*, p. 287). They inherited professional codes and skills handed down from one generation to the next within the family groups rooted in empirical knowledge and in the practical experience of everyday life. This experience, today referred to as intangible heritage, is one in which community and economic activity, coexisting simultaneously in one place, constructed a specific cultural heritage.

The territory of this fishing community included their own backyards ashore, which were organised through a system of agricultural land use known as "*masseiras*"[7], but also included the "seas" of each family.
The house and the boat were both situated on the beach, a frontier region that allowed for a continuous use of the territory, in a transversal system that guaranteed the subsistence of the community (Fig. 4).

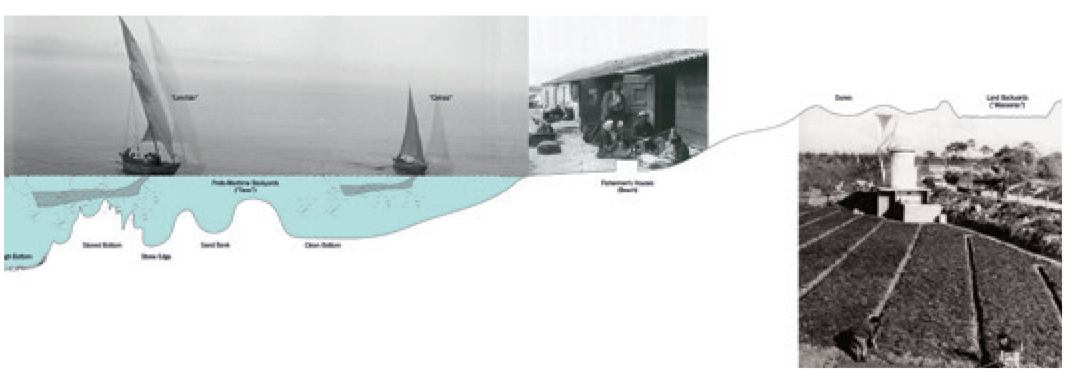

FIGURE 4 Crossovers in the use of the territory between shore and sea.

4 Poveiros – Name given to the fishing community in Póvoa de Varzim.

5 An agglomerate of seaweed harvested and dried on a seasonal basis, and used as a natural fertiliser for the sandy soil close to the coast.

6 Among these "castas" were the "rasqueiros", who used a "rasca" (trawl-net) to fish for ray, lobster, and crab; the "sardinheiros" (sardine fishers) or "fanequeiros" (whiting-pout fishers), who used a "pano" (gillnet) or "trole" (hook and line fishing). Master "Espojeiro" belonged to the "caste" of the "sardinheiros" or "fanequeiros" and either used nets or engaged in line-fishing.

7 A unique form of traditional farming practised along the coast of Póvoa de Varzim.

It is worth noting the transfer of vocabulary from land to sea, with words such as "field" and "backyard", references to agricultural practices, being used to describe the space of the sea. Examples of the farming vocabulary used by Master "Espojeiro" and transferred to fishing included words such as "*caça*" (hunt), used to refer to a set of nets, "*safra*" (crop) to describe the quantity of fish caught, and "*ceifa*" (harvest) to indicate the time that the nets remained in the sea.

With the information that Master "Espojeiro" provided, we were able to understand the forms of the spatial relationship established between the fishermen and the sea. Using their empirical knowledge of the sea's dynamics to develop their own ways of interpreting and taking ownership of its behaviour, they made it a natural part of their own habitat. The master showed us the main tool that they used for interpreting the maritime space: a handmade probe that measured the depth of the sea and indicated the characteristics of the seabed. With this information, the fisherman was able to know what kind of fish could be caught in a certain area. The probe consisted of a length of rope that indicated the number of *braças* (fathoms – each *braça* measured 1.82 metres) and had a hollow lead cylinder at its end that was filled with tallow. When the probe hit the seabed, it was hauled back up again, the depth of the column of water was measured, and the tallow brought with it the information about the type of seabed in question. This information, which was rarely recorded on the maps and charts, was stored in the master's memory, and was then used to mark out the areas to be exploited by each family. The fishermen also knew the behaviour of each species of fish and were able to use this knowledge to determine the place and the length of time during which they should work with each kind of fishing technique, which varied according to the time of day and the season of the year.

Besides this, the community also established its own toponymy for dividing up the maritime territory that each "caste" could use. Under the scope of the research that he undertook into the *Poveiros*, (Martins, 1999) describes the classification of four seas, according to its depth:

- "*Mar da beirada da terra*" ("edge of the land") extended from the coastline up to a depth of 20 fathoms, with the seabed consisting predominantly of stones, its limits being demarcated by the last ridge of rocks before the land, when coming from the sea (east).
- "*Mar das pedradas da faneca*" ("whiting-pout stones") found at a depth of roughly 38 fathoms, with the seabed consisting mainly of silt or sand, as well as scattered stones of varying sizes.
- "*Mar da beirada de fora*" ("outside edge") situated at a depth of between 58 and 63 fathoms and defined by the last outside edge (west) of the rocky ridge (as, for example, the Pontal do Cerro indicated on the map) (Fig. 2).
- "*Mar dos Profundos*" ("deep sea") had a depth of more than 200 fathoms, beyond the reach of the portable probe.

Master "*Espojeiro*" also specified other areas within these seas, according to the characteristics of their seabeds:

- "*Regueiros*" ("furrows") composed of two large rocks between which there was a small depression filled with "*cascalho*" (fragmented rocks) or "*burgalho*" (pebbles).
- "*Bancos de areia*" (sand banks) composed of hills of sand and small depressions also filled with sand.
- "*Fundo limpo*" (clean bottom) composed of sand, silt or mud.
- "*Fundo Raso*" (flat bottom) composed of a long ridge of smooth rocks.
- "*Fundo Grosso*" (rough bottom) composed of small stones, such as pebbles.

Each of these morphologies and features of the seabed, depending on the depth of the water column, corresponds to certain kinds of marine species. This knowledge of the traditional fishing activity was the basis for the creation of the "maritime backyards".

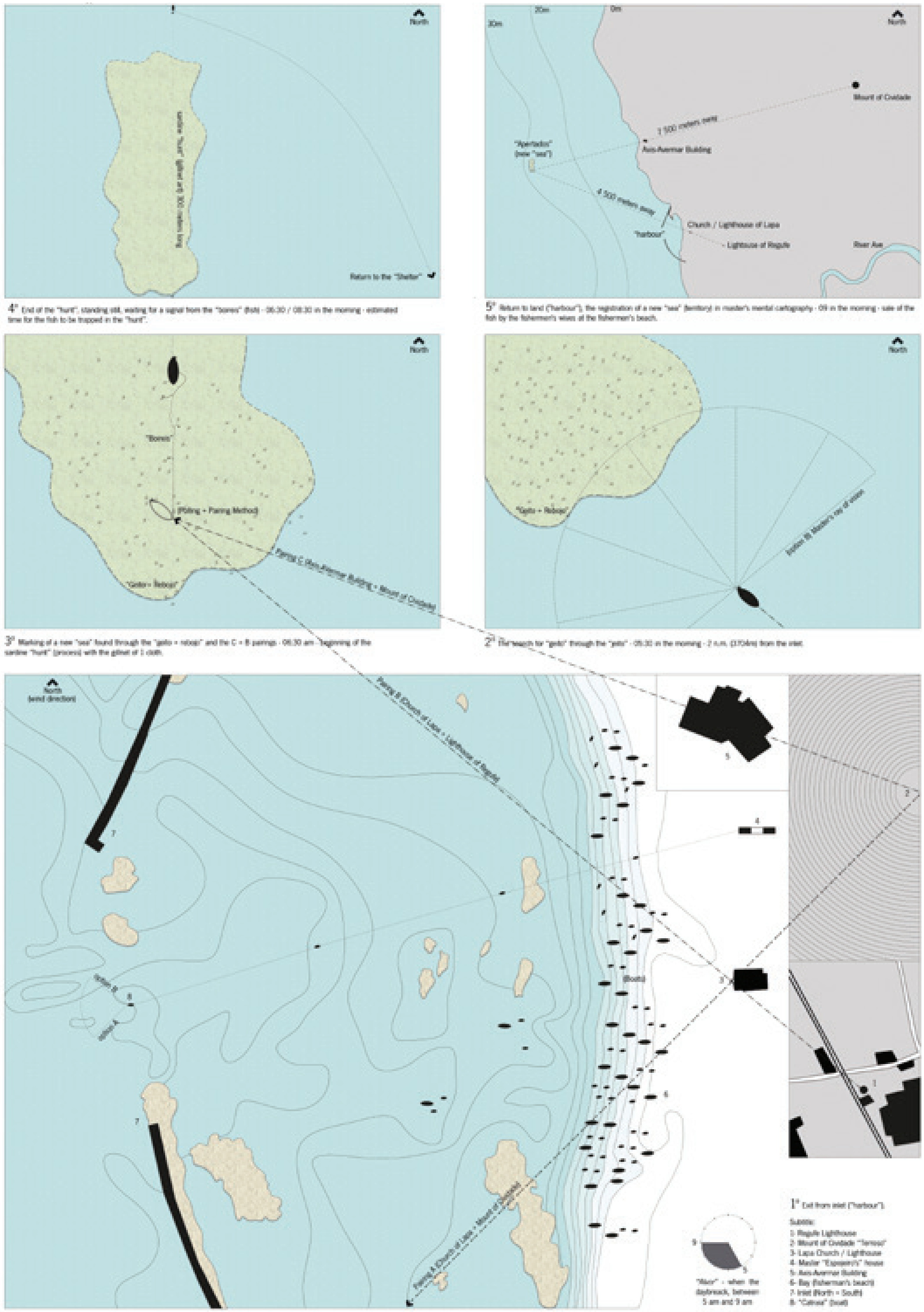

FIGURE 5 Stages in the creation of a new “sea” in Póvoa de Varzim in the culture of artisanal fishing.

The Creation of a “Sea” in the Memory of Master “Espojeiro”

The process of creating a “sea” has various scales and spatial relationships that depend on the routine of a particular master and his crew. In order to represent this, it was necessary to make a detailed description of the actions that comprised the routine of Master “Espojeiro” using the map drawn up by Gormicho (1948) as the basis for drawing the method for this chapter.

Master “Espojeiro’s” day began on the fishermen’s beach, observing the behaviour of the sea and the weather conditions favourable to fishing. Then the fishermen would head out at daybreak from the “harbour” (inlet), with their sail raised, always remaining in line with two landmarks ashore. The sea’s behaviour and the weather are unpredictable, so each master’s methods for finding the fish were crucial for the success of each crew. These methods were known as the particular master’s “*jeito*” (knack), which began with the reading of the behaviour of seabirds. They were also known as “*geito*”, which suggested the direction that the boat should head in as it left the harbour. These birds fly at a height of seven metres and dive repeatedly into the water, reaching up to three metres in depth, in order to capture, for example, sardines. Their diving indicates the position of the shoals of fish. Similarly, the yellowish colour of the water’s surface, caused by the sea’s roughness and known by the name of “*rebojo*”, indicates the presence of shoals. These two methods, among others, made it possible to identify areas where it was presumed that fish would be found in abundance. However, before beginning to release the nets, the master memorised the place through the two visual markers and attributed a name to the new “sea” based on its particular identifying characteristics. One example was the christened “sea” by Master “Espojeiro”, with the name of *Apertados* (“narrow”) due to the characteristics of the seabed: a narrow sand bank that was the width of the boat (Fig. 5).

During the “*faina*” (fishing trip), which lasted between three and five hours, the fishermen’s wives and children would remain on the beach repairing the nets. On returning to the inlet the location of the privileged fishing points, the new “seas”, was kept secret, or shared among family members, giving rise to common mental maps. Consequently, some of these “seas” had more than one name as various masters discovered them on different occasions. The fisherman’s memory was the greatest intangible heritage of each family, representing an immaterial legacy that could be handed down to his descendants. In parallel to this, the boat and the fishing gear were the most important material legacy, inherited by the youngest son.

Póvoa de Varzim: The contemporary fishing sea space method

In 1895, movable fishing gear (trawling and purse seine) began to be introduced at Póvoa de Varzim, as well as steam-powered boats. This gear was fostered by the canning industry, which operated all along the coast, proving to be a decisive factor in the urban transformation of the area (Filgueiras, 1981, pp. 220-302). The first consequence of these changes was the progressive increase in the impact of fishing on the marine fauna and flora. Trawlers could capture in just one “crop” quantities that were equivalent to the total catch made by all the local fishing boats in one month (Pardo, Queiroga, Pierce, & Grilo, 2017). By increasing the pressure on the species and stimulating the fishing economy, the modernisation processes ended up endangering their own source of income. According to the French ecologist Didier Gascuel, unlike agriculture and industry, in the case of fisheries, the more that is invested in the means of production, the less is actually produced, inasmuch as the natural resources are limited (Gascuel, 2019). Over-investment ends up leading to an exhaustion of resources.

The changes introduced into production with the industrialisation of the procedures followed in the processing of the catch led to a change in fishing practices. Sailing boats were gradually replaced with boats that were powered firstly by steam and then by diesel. The development of the motor-boat, and the consequent increase in the size and number of such vessels, made it necessary to enlarge and improve the berths at the quayside, bringing an end to the direct relationship between the beach and the sea. The coastal landscape of Póvoa de Varzim gradually began to change as its economic activities became more modernised, with clear impacts on the town's urban and social fabric (Saldanha, 2008. pp. 141-143). (Fig.6)

FIGURE 6 Change of the built environment of the former fishermen's beach to the present-day fishing port of Póvoa de Varzim.

This dynamic was accompanied by another one, which was perhaps even more important, in which fishermen ceased to participate in the production of their own working instruments. And it was in the course of this transitional process that the mental maps of the "seas" ceased to be important, being replaced by other navigational mechanisms and other devices that can be used for identifying the reserved areas for fishing.

These transformations led to the progressive abandonment of traditional fishing practices in Póvoa de Varzim, with fishermen developing new strategies for the performance of their methods.

An example of this adaptation (Martins, 1999), was the work initiated by the company of *Gerónimo Viana*, who invested in the fixed fishing gear of *alcatruzes* (pots) and introduced the system of "maritime backyards". This system was designed to reduce the characteristic unpredictability of fishing, by combining the traditional knowledge of the "seas" with the new technologies (Fig. 7). The technique of fishing with pots began to be developed in an informal way from the 1980s onwards: in the first phase, clay pots were used, which were later replaced by cylindrical plastic pots. The State only regulated this fishing technique in 1989, adapted for the capture of octopus (Martins, *op. cit.*, pp. 235-270). The development of this system among the fishermen from Póvoa de Varzim led to attempts to reserve portions of sea and specific places so that each fisherman could fish in this way on a permanent basis. These fishing practices were adapted accordingly to a master who discovered a place where no fishing technique had yet been implemented, thus giving him the right to reserve that new "maritime backyard" for himself, attributing it with a place name and registering its coordinates. In this way, a system of "maritime backyards" was initiated, which then became stabilised between fishermen and groups of fishermen.

FIGURE 7 Example of annotations of the various place names of "seas" made by a fisherman from Póvoa de Varzim, on a map between the traditional memory and the record of digital coordinates. (Anonymous owner)

In Póvoa de Varzim, the polyvalent technique simultaneously uses various fishing gears in just one boat (DGRM, 2019). As it proved possible to discern by watching the ship's owner and its crew in action, this polyvalent fishing technique represents a synthesis between traditional practices and contemporary technologies. The territory of the "maritime backyards", in general, makes use of pots combined with trammel nets. Currently, each fishing licence is attributed to the boat's owner or skipper. A "local skipper" can navigate and fish between two ports within a limit of six nautical miles in relation to the coastline. The "coastal skipper" can navigate along the whole coast without exceeding the limit of fifty nautical miles in relation to the coast, which is also the limit of the Exclusive Economic Zone. (DGRM, 2019). These categories also correspond to the characteristics of the boats, such as their breadth, tonnage, engine power, and communication equipment. The boat continues to be the most important element for fishing. Besides being both the means of transport and the working tool, it is also a temporary home when the time spent on board is more extensive. In traditional fishing, the boats used to set out at dawn and return to the beach in the evening. In contemporary fishing, activities can spread over several days and, sometimes, over several weeks.

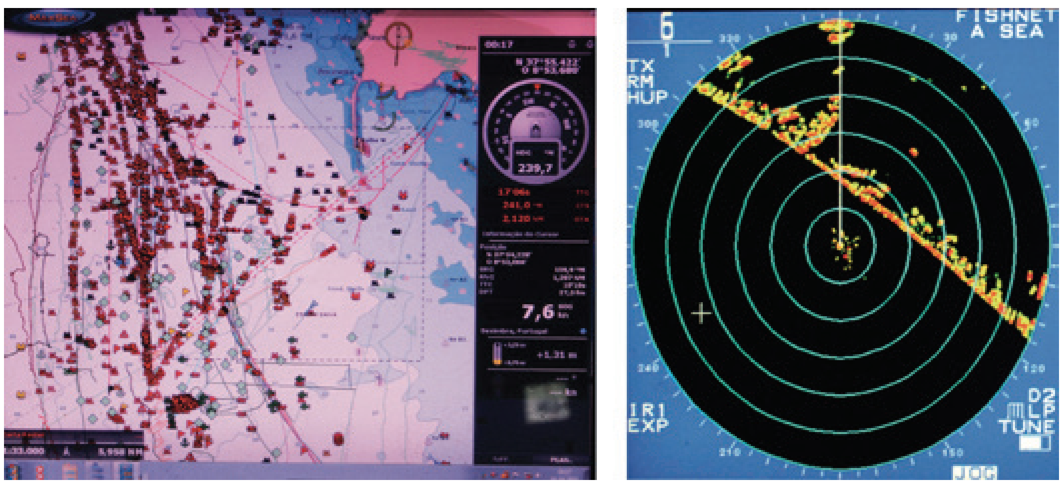

FIGURE 8 A Max Sea digital map at the moment of choosing the destination of fishing (left) and the electronic radar (right) with information about the objects within a radius of six nautical miles around the boat.

In the last few decades, electronic instruments have entered into widespread use as an aid to navigation. The master showed how these instruments were used to control the vessel, take decisions and establish strategies in accordance with the weather conditions, the wind, the temperature, the characteristics of the seabed, and the typical behaviour of the species at each moment of the year. The former "*jeito*" of traditional fishing has been replaced by procedures for reading and navigating in the maritime space through coordinates processed in computer applications such as MaxSea[8]. This programme integrates the information captured in real time by various instruments (GPS[9] and AIS[10]) (Fig. 8). The sharing of this information makes it possible to obtain the position, the characteristics, and routes of other vessels. The sonar replaced the handmade probe in the reading of the conditions and characteristics of the seabed.

8 Developed by the company Time Zero, Navigation Software. Another software application that is widely used in Portuguese shipping is the AIS system developed by ARPA Targets.

9 GPS - (Global Positioning System)

10 AIS (Automatic Identification System)

Once the reading of the variables of the "seas" mental map method was determined by the "*jeito*" of the master, but is now performed through these common instruments that are constantly updated. This new cartography, based on digital tools, is produced by each fisherman and is associated with physical markers placed in the sea: the marker buoys.
It is these buoys that identify the ownership of the "backyards" and the limits of the "backyards" are defined by the art of pots, which the fishermen refer to as "stone walls" (Fig. 9), since the pots are similar in appearance to the stones under which the octopus shelters and reproduces. Besides defining the size of a backyard, the "stone walls" also divide their interior into areas associated with various species. Normally, these separate areas (plots) define minimum distances of 150 and 200 metres between each "hunting ground" in order to enable each species to reproduce without overexploiting its habitat. These divisions enable the master to work in the same backyards throughout the year, using bathymetric lines that allow him to divide his time according to the state of development of each species.

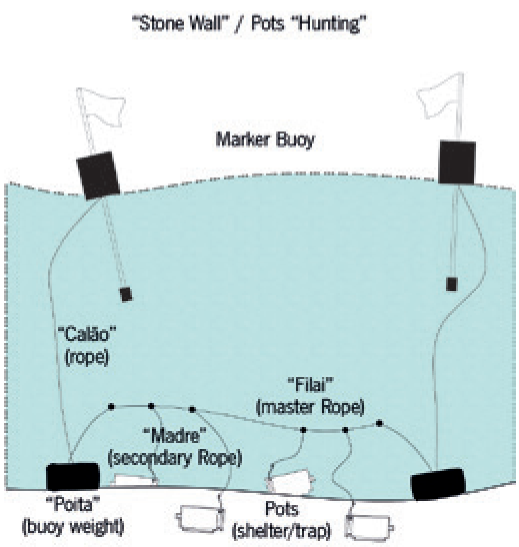

FIGURE 9 Structure of a "stone wall" made of pots in a "maritime backyard".

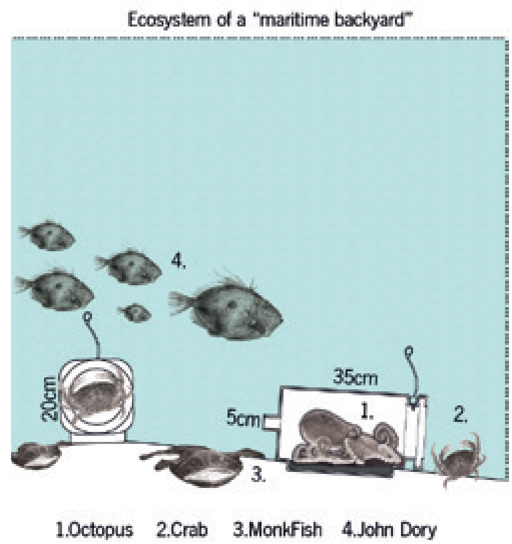

FIGURE 10 Representation of the ecosystem generated in a "maritime backyard".

The maritime backyard that we were able to analyse was divided into two separate areas of fish: John Dory (*Zeus faber*), which is more frequently found in stone beds, halfway down the water column, and monkfish (*Lophius piscatorius*), which is a fish from the seabed normally caught in pebbly sand. Besides having different capture times and depths, the two fish require different uses of the same fishing gear: trammel nets, in the case of John Dory, stretched out vertically in the form of a "wall", and, for monkfish, horizontally in the form of a "bed". The octopus, one of the prey of these fish, attracts its predators to the rocks where it finds shelter, also attracting there the crab, which, in turn, feeds off these fish and serves as food for the octopus. As it happens, the "stone walls", are used by the octopuses to protect themselves from their predators and to procreate, serving as a dwelling place. The octopuses use the trap to reproduce without falling prey to the fish, taking advantage of the crabs' shells to cover the exit from the pot (Fig. 10).
The fact that the octopus is a predator of the crab, which would be the predator of the fish, favours the reproduction of the John Dory and monkfish within the separate areas of the backyard. This dynamic of the trophic chain makes it clear that the fishing gear ends up creating its own ecosystem. If this cycle is managed in a balanced way, it makes it possible to capture and stimulate the reproduction of various species, guaranteeing over time the production of each of these "nurseries". The construction of this system of "maritime backyards" allows the fishermen to organise the maritime space and reproduce submerged landscapes, themselves becoming genuine architects of the sea.

The Creation and Exploitation of a "Maritime Backyard"

The process began at the port, with the consultation of the digital tools (Fig. 11). An "empty" space was located, and the boat set out on automatic pilot in accordance with the GPS. On the bathymetric line at a depth of 38 metres, a marker buoy was placed in the water (point A), from which pots were then dropped into the sea along a 2.5-kilometre-long line (450 pots) on the "outer" western side of the new backyard, as far as point A'. Next, the boat moved to point B, defining a new segment with a straight line on the "inner" eastern side, in the form of another bathymetric line at a depth of 36 metres as far as point B´. The fourth step was to divide the backyard into two plots, with a "stone wall" between points C and C´, consisting of 50 pots along a 250-metre stretch, in an operation that is referred to as "closing the backyard". The coordinates of the boundaries are recorded in the MAXSea (Fig. 12). Until five o'clock in the morning, before dawn, various walls of other backyards are "emptied", as this is a time when the octopus is sleeping (Fig. 13). And, between five o'clock in the morning and three o'clock in the afternoon, the nets that had been cast two days earlier in an area close to the new backyard in order to catch the John Dory and the monk fish are hauled up (Fig. 11). This time is particularly advantageous, since it is during this period that the John Dory and monkfish come out of their shelters to look for food, increasing the possibility of their becoming trapped in the nets. The fishermen then return with a fully laden boat to the port (Fig. 14).

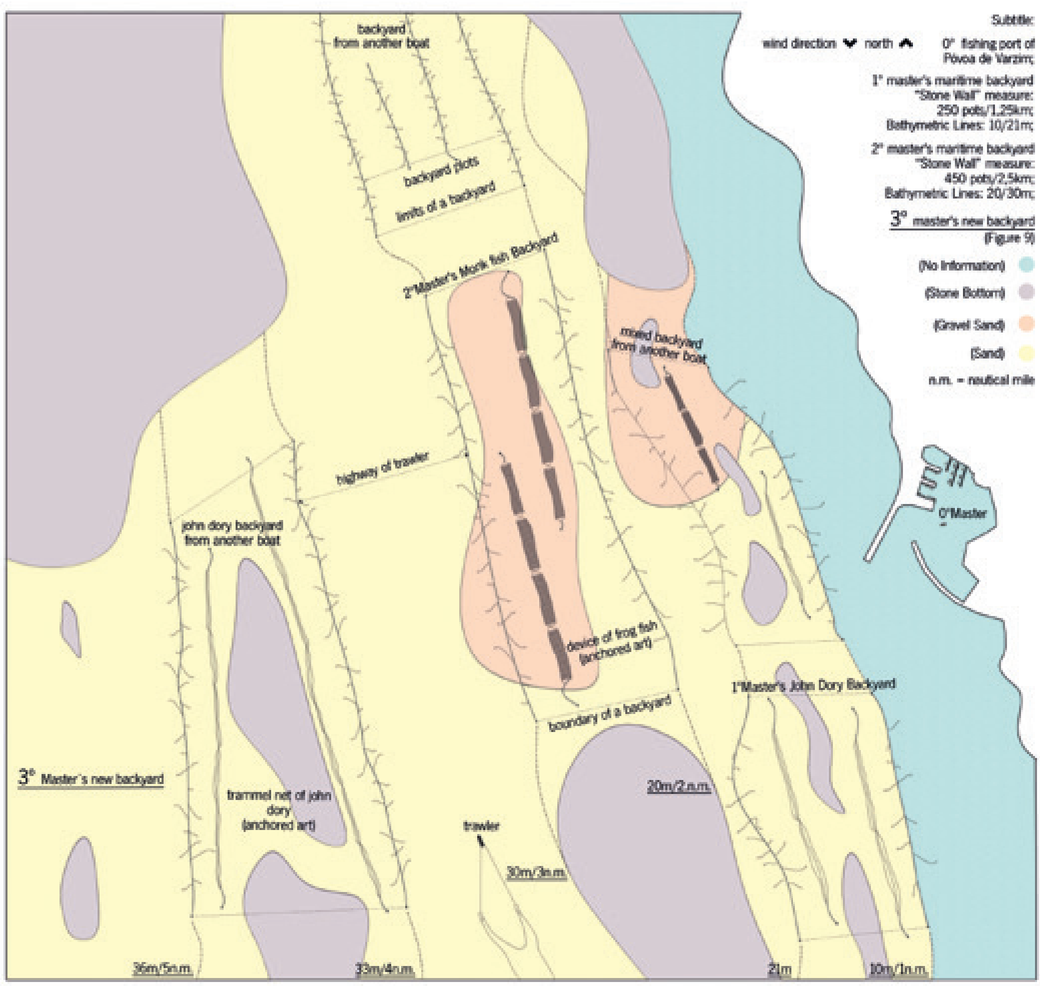

FIGURE 11 Territorialisation of various "maritime backyards" off the coast of Póvoa de Varzim.

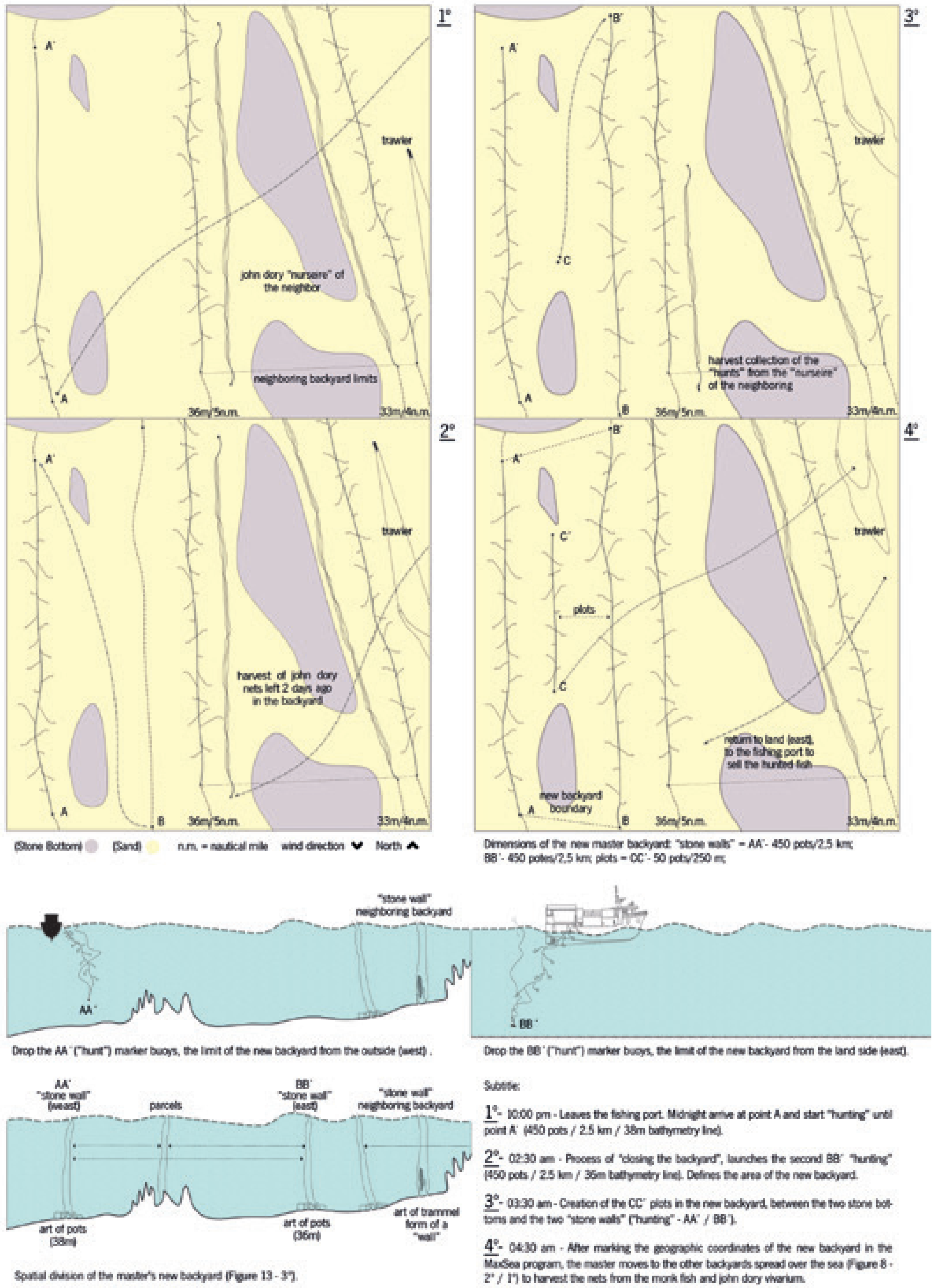

FIGURE 12 Stages in the creation of a new "maritime backyard".

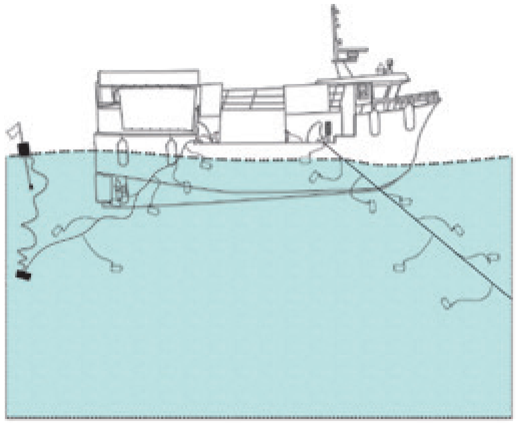

FIGURE 13 Process of emptying the pots. A “stone wall” is repositioned in the same backyard, simultaneously pulling in and letting out the line in order to preserve the territorial marking of the system.

FIGURE 14 Fieldwork.

Conclusions

The fishing activity undertaken in Póvoa de Varzim has adapted to the nature of the maritime territory, appropriating the space. The establishment of a system of “maritime backyards”, today corresponds to a unique and informal territorialisation process that allows for a cross reading of the activities between sea and shore. Because of its scale and dimension, the system is a synthesis between industrial fishing processes and traditional practices, which results in techniques with virtues that are comparable with those of aquaculture, but also guarantee the necessary dynamics and natural environments for the development of the different marine species. Through this system is possible to stimulate, control, and respect the interactions between the different levels of the ecological community, and allow for the development of new submerged landscapes and ecosystems. The specific spatiality of the sea is recognised using fishing gear, through the marker buoys that represent the human reserve area and produce a cartography that allows for a specific reading of this territory.

It is interesting to note the reciprocity that exists between the fishing gear, the marine resources, and the forms and mechanisms that exist for the mapping of these processes and the different ways of territorialising the sea. In this work, based on personal experience and interviews with fishermen from Póvoa de Varzim, it was possible to understand the way in which the use of the information transcribed into maps is directly linked to the evolution of the devices used (firstly analogue and then digital), with practical consequences for the ways and means of appropriating the marine territory (firstly temporarily and then permanently).

With this research process we produce these new cartographies, seeking to highlight the role played by the sea as a territory, considering it as a fundamental submerged landscape for understanding the environments built along the coast, as well as the role played by the exploitation of marine resources, especially in terms of fishing and its different forms of territorialisation.

Acknowledgements

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References

Amorim, A. S. (2004). Vencer o mar ganhar a terra: construção e ordenamento dos espaços na póvoa pesqueira e pré-balnear. In *Collection Vol. 8 Na linha do horizonte - Biblioteca Poveira [On the horizon - Poveira Library*]. Edition of Póvoa de Varzim municipal chamber ISBN 972-9146-35-7 *pp.35*. Retrieved from http://bibliografia.bnportugal.gov.pt/bnp/bnp.exe/registo?1586717.

Areias, M. (1997). Os pescadores poveiros nos 'mares' de Aveiro" in *Boletim Cultural da Póvoa de Varzim*, v. 16, no. 2, (p. 287) [Online]. Edition of Póvoa de Varzim municipal chamber. Retrieved from https://www.memoriamedia.net/bd_docs/transcrioes_Povoa/os%20pescadores%20poveiros%20nos%20mares%20de%20Aveiro.PDF.

Bibliography of the *Boletins Culturais sobre o Património marítimo da Póvoa de Varzim* (n.d.). Retrieved from http://web.cmpvarzim.pt/lanchapoveira/index.php?option=com_content&view=article&id=10&Itemid=12. Accessed on 2 December, 2019.

Cadilhe, J. P. (1997). As 'conhecenças' dos pescadores poveiros" in *Boletim Cultural da Póvoa de Varzim*, v. 16, no. 2, pp. 157-173. [Online]. Edition of Póvoa de Varzim municipal chamber. Retrieved from http://web.cmpvarzim.pt/lanchapoveira/images/documentos/bibliografia/boletim_cultural/bc_xix_1_5_34.pdf.

Filgueiras, L. O. (1981). *Barcos de Pesca de Portugal* [*Fishing Boats of the Portuguese Coast*]. Edition from Centro de Estudos de Cartografia Antiga [Ancient Cartography Study Center]. Offprint from the *Revista da Universidade de Coimbra* [*University of Coimbra Magazine*], vol. CXXXVIII. Digital edition, pp. 220-302. Retrieved from https://museumaritimo.cm-ilhavo.pt/pages/183.

Firth, R. (1975). *Malay Fishermen – Their Peasant Economy*. New York: The Norton Library.

Forman, S. (1970). *The Raft Fishermen: Tradition & Change in the Brazilian Peasant Economy*. Bloomington/London: Indiana University Press.

Gascuel, D. (2019). *Pour une révolution dans la mer* [For a revolution in the sea]. Arles: Actes Sud.

Hydrographic Institute of Portugal & IPMA (2017). *Carta da Série – Pescas, Oceano Atlântico Norte, Portugal Continental – Costa Oeste: Caminha a Aveiro* [*Series Letter - Fisheries, North Atlantic Ocean, Continental Portugal - West Coast: Caminha and Aveiro*] Retrieved from https://www.prosea.pt/pt/products/caminha-a-aveiro-24201.

Gormicho Boavida, J. (1948). *Roteiro da Pesca de Arrasto da Costa Continental Portuguesa*. Edição da Revista Boletim da Pesca [*Trawl Fishing Route of the Portuguese Continental Coast*. Edition of the Fishing Bulletin Magazine] – Subsidised by the *Grémio dos Armadores da Pesca de Arrasto* [Guild of Trawler Owners]. Portugal: Lisbon.

Lueck, D. (1993). Contracting into the Commons. In T.L. Anderson & R. T. Simmons (Eds.), *The Political Economy of Customs and Culture: Informal Solutions to the Commons Problem*. pp. 43-59. Boston: Rowman & Littlefield

Martins, L. (1999). *Mares eletrónicos em fundos sem peixe: um estudo de caso na Póvoa de Varzim e nas Caxinas.* [Electronic seas in bottom without fish: a case study in Póvoa de Varzim and Caxinas]. *Etnográfica* [Online], vol. III, no. 2, (pp. 235-270). Accessed on 18 November, 2019.

Matthews, D. R. (1993). *Controlling Common Property: Regulating Canada's East Coast Fishery.* Toronto: University of Toronto Press.

McGoodwin, J. R. (1989). *Conflicts over shrimp rights in a Mexican fishery*. In J. Cordell (Ed.) *A sea of small boats.* Cultural Survival Report no. 26 pp. 177-201. Cambridge, MA: Cultural Survival, Inc.

Mustain, A. (2011). *Mysteries of the Oceans Remain Vast and Deep. LiveScience* [Online]. Retrieved from: https://www.livescience.com/14493-ocean-exploration-deep-sea-diving.html . Accessed on 12 April, 2020.

Pardo, B. J., Queiroga, H., Graham, P. J., & Grilo, C. (2017). *Pesca do arrasto em Portugal. E se fosse em terra?* (Edition Lisbon: Fundação Calouste Gulbenkian) [Online]. Policy brief produced in the context of the research project *The Economic Valuation and Governance of Marine and Coastal Ecosystem Services*. Retrieved from: https://gulbenkian.pt/publication/pesca-de-arrasto-em-portugal/.

Saldanha, J.B. (2008). *A causa do mar em Manuel Lopes* [The cause of the sea in Manuel Lopes]. [Online] Edition of Póvoa de Varzim municipal chamber, v. 42, pp. 141-143. Retrieved from: http://web.cm-pvarzim.pt/lanchapoveira/index.php?option=com_content&view=article&id=10&Itemid=12

Santos Graça, A. (1982). *O Poveiro: usos, costumes, tradições lendas. [O Poveiro: uses, customs, traditions, legends]* Póvoa de Varzim: Câmara Municipal da Póvoa de Varzim (2nd Ed.) Facsimile re-edition of the author's own publication from 1932 (Original work published 1933).

Sinclair, P. R. (1985). *From Traps to Draggers: Domestic Commodity Production in Northwest Newfoundland 1850-1982*. St. John's, Newfoundland, Memorial University of Newfoundland, Institute of Social and Economic Research.

Participatory Management of Traditional Urban Water Infrastructures in Iran

The Case of Tehran Historic Qanats

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Abstract

Qanats have played a vital role in underground water extraction since ancient times based on the community-based water management schemes in Iran. Due to recent urban sprawl and development pressures, qanats are progressively abandoned and degraded in the cities and are considered as endangered assets. To be sustainable, in addition to physical maintenance, the ecological and social aspects of qanat management systems, as the main characteristic of Urban Water Infrastructures in Iran, also need to be taken into account. A review of the traditional participatory management systems in Iran, as well as the contemporary community-based interventions (CBI) in the context of qanats, demonstrates the significant role of public participation in this regard. This research aims to provide solutions and recommendations for enhancement of stakeholder engagement in contemporary qanat rehabilitation practices by adapting the traditional communal management techniques and multi-stakeholder approaches to qanat maintenance in Iran. For this purpose, the transformation of the key urban water stakeholders from past to present are studied and mapped based on their roles and influence on decision making process for the management of qanats. The resulting illustration of the stakeholders' networks and the comparative study of inter-relationships not only reveals today's institutional gaps and missing links in qanats' management procedures, but also highlights the former community-based coordination mechanisms that used to support the smooth functioning of this socio-technical infrastructure by promoting constructive interactions among conflicting parties. In order to tackle contemporary governance challenges, this research also provides a set of practical recommendations to adjust those traditional learnings to new conditions by addressing the physical, environmental, and socio-cultural aspects of qanats in Tehran.

Keywords traditional urban water infrastructures, stakeholders engagement, community-based partnership, qanat rehabilitation, qanat, participatory approach

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Introduction

The central plateau of Iran which is surrounded by Alborz and Zagros mountain ranges from north and west, has long been an arid region. Due to aridity and water scarcity of their land, ancient Iranians had to periodically switch their settlements between mountains and plains in search of seasonal water resources (Estaji & Karin, 2016). Lack of year-round water supplies like rivers made it hard for societies to adopt sedentism. However, around 3000 years ago, ancient Iranians could devise an innovative and sophisticated hydraulic structure, termed “qanat” or “kariz”, which enabled them to access groundwater resources.

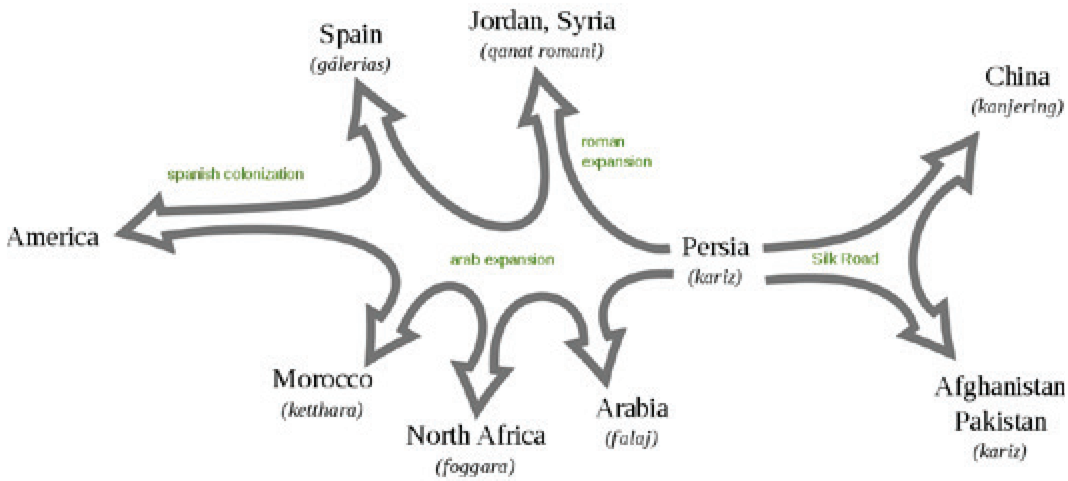

FIGURE 1 Probable diffusion of qanat technology (“Qanat,” n.d.).

The idea of a qanat system was gradually exported to other areas of the world including Iraq, some African countries, parts of Europe, and China (Maleki & Khorsandi Aghaei, 2006) (Fig. 1). However, Iran, as the origin of the qanat, has possessed the greatest number of qanat systems throughout the history of civilisation. In its 40th session in July 2016, the World Heritage Committee of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) inscribed the “Persian Qanats” property on the World Heritage List. The World Heritage Committee recognised the Outstanding Universal Value (OUV) of the property notably because of its authenticity and integrity and the following criteria for OUV properties:

A The Persian Qanat system is an exceptional testimony to the tradition of providing water to arid regions to support settlements. The technological and communal achievements of the qanats play a vital role of qanat in the formation of various civilizations. Its crucial importance for the larger arid region is expressed in the name of the desert plateau of Iran which is called “Qanat Civilization”.

B The Persian Qanat system is an outstanding example of a technological ensemble illustrating significant stages in the history of human occupation of arid and semi-arid regions. Based on complex calculations and exceptional architectural qualities, water was collected and transported by mere gravity over long distances and these transport systems were maintained over centuries and, at times, millennia.

A Qanat system (Fig. 2) mainly consists of an inclined underground tunnel connected to some shaft wells along its path which transfers groundwater from an aquifer to the earth surface. The place where the gallery and the ground surface eventually intersect is the qanat’s outlet where the water appears. The vertical shafts sunken along the horizontal gallery are used for lifting up excavated material from the tunnel to the surface. They also provide access and ventilation for the tunnel. Water coming from qanats was used for diverse purposes by means of different supplementary elements, including ditches and streams that transferred water to farmlands, water reservoirs that supplied water for domestic or public use, etc. (Semsar Yazdi & Labbaf Khaneiki, 2017).

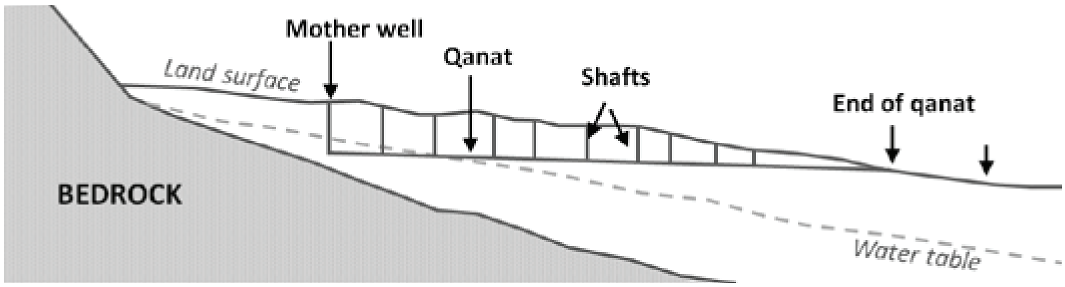

FIGURE 2 Schematic section of qanat (Manuel et al., 2017).

In addition to the qanat's role in the initial establishment of human settlements, cities' physical expansion and population growth were influenced by the amount of their qanats' water supply (Aghazadeh, 2013). Furthermore, qanats affected urban pattern; if they were close to each other the city became compact and dense. Additionally, the overall direction of farming lands and cities obeyed the qanat's direction, an attribute that helped the urban structure to better adapt to the arid climate of the region (Shiraazi, Milani, Sadeghi, Azami, & Azami, 2012) (Fig. 3).

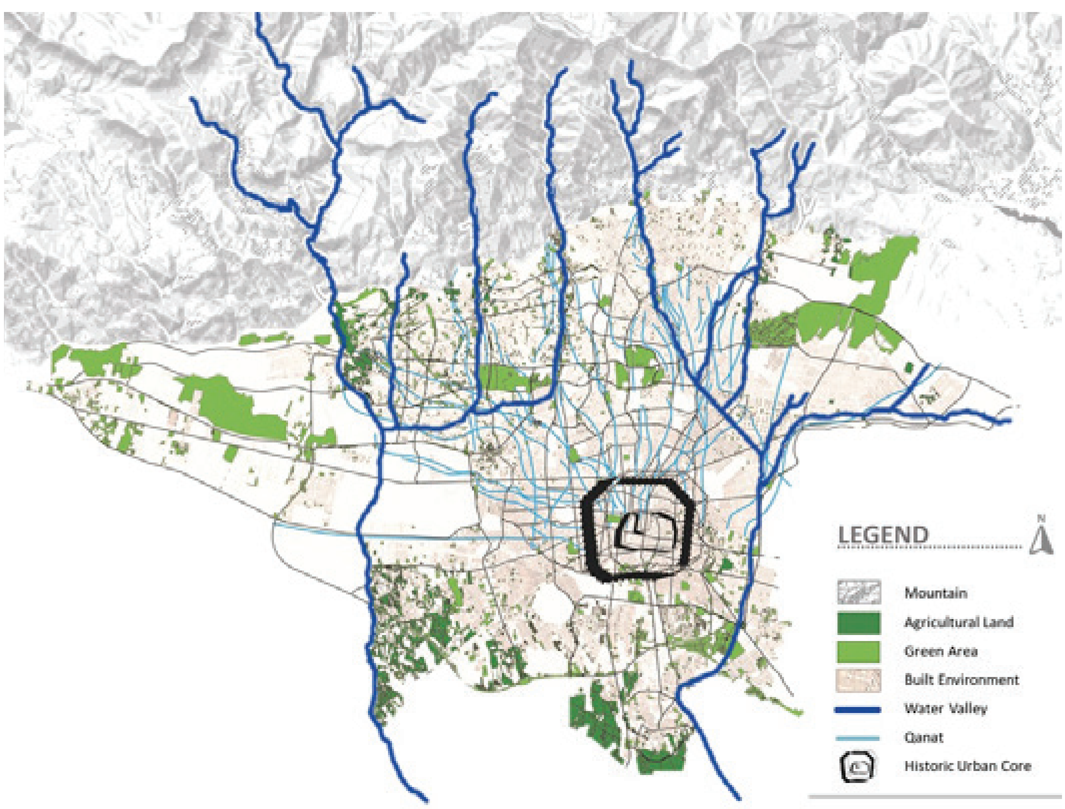

FIGURE 3 Schematic map of Tehran: location and green areas shaped by Qanat network.

Qanats continue to provide the essential resource water that sustains Iranian settlements and gardens, and remain maintained and managed through traditional communal management systems (ICHHTO, 2015). Currently, there are nearly 50,000 qanats in Iran, more than 200 of which, with a total length of 2,000 km, are located in the capital of Tehran (Zivdar & Karimian, 2019).

The existing literature on the qanat is quite extensive; it encompasses research from various perspectives, including the qanats' historical background and heritage value, the technical mechanism and engineering knowledge behind qanat construction and operation, qanats' ownership laws, and irrigation management traditions (Khaneiki, 2019, paras. 11–15). Yet, the greatest share of the available literature on the qanat has been produced in the technical realm. In their book *Qanat Knowledge*, Semsar Yazdi and Labbaf Khaneiki (2017) give a thorough description of the qanat's hydrological mechanisms and the technical mastery of qanat diggers. Several scholars have examined the impacts of modern water provision technologies, on qanats' deterioration and abandonment, and their replacement by deep wells over the past century (Bonine, 1996; English, 1968; Hussain, Abu-Rizaiza, Habib, & Ashfaq, 2008).

Apart from being an infrastructural element created by engineering knowledge, qanats have been of great importance from a socio-cultural perspective. In fact, the qanat was a socio-technical system whose ownership and management depended on a community-based partnership, rooted in collective practices of several shareholders. Despite the prevalent technical viewpoints in qanat literature, there are several research works conducted on the qanat with a focus on socio-cultural facets. Bonine (1996) investigates the social and cultural characteristics of qanat systems in Iranian rural areas. In his paper, he put an emphasis on the former common irrigation rules and qanat management practices (Bonine, 1996, pp. 195-201). hrough examining the available resources and case studies from four middle eastern countries Hussain et al. (2008) defined a qanat as "an established socio-cultural institution which involves shared expectations and pattern of cooperation and conflicts. It is a pivot around which different community activities take place" (p. 334). Therefore, social factors, which include "social cohesion in community, social participation, cultural values, and community leadership" go hand in hand with technical conditions and structure, to facilitate qanat's smooth functioning (Hussain, Abu-Rizaiza, Habib, & Ashfaq, 2008, p. 346).

In the regions where qanats are the cornerstone of the local economy, community cooperation is significant. This cooperation also spreads to the other realms of social life and comes to turn into a sort of cultural genetics (Semsar Yazdi & Labbaf Khaneiki, 2017, p. 2). Some scholars have made attempts to translate these traditions to management models and frameworks. Khaneiki (2019) explored the cooperation taking place between a number of territories using the same qanat, in achieving a participatory water management system which ensured fair water distribution. Based on the insights from a case study in arid regions of Iran, he formulated a territorial water cooperation model (Khaneiki, 2019). Building his work on the explanations given by Semsar Yazdi (2014) about Zarch qanat stakeholders and the traditional collective water management patterns, Salek (2019) generated a theoretical framework based on Actor-Network Theory, to guide the transition from a centralised water management regime towards a participatory, community-based water governance style.

The emergence of modern hydraulic structures like deep wells, dams, reservoirs, and piped water supply systems resulted in a decline of qanats. However, many places and local communities are still solely dependent on the qanat water supply. In such cases, besides water distribution, community cooperation takes place in the maintenance and repair of qanats. In the paper, "Renovation of Qanats in Syria", Wessels and Hoogeveen (2002) developed some feasibility criteria for qanat renovation in the Middle East. They included "strong social cohesion in community" and "willingness of water users to contribute" among the six renovation criteria they developed, which are essential in all community-based interventions (CBI) (Wessels & Hoogeveen, 2002). Wessels (2005) also described two CBI projects carried out within a wide development study on traditional water management in Syria. The study follows a Participatory Action Research (PAR) approach in which a CBI is developed to investigate the social and physical possibilities of renovating a qanat at community level. These projects involved the strong commitment of external actors in the facilitation of the CBI (Wessels, 2005).

In a 2019 study, Zivdar and Karimian (2019) focused on Mehrgerd Qanat, a 700-year-old infrastructure running through a densely populated urban district of Tehran. Even though their work mainly concentrates on the analysis of the qanat's landscape based on the Heritage Impact Assessment (HIA) method, they criticise the negligence of community participation in current practices of qanat revitalisation (Zivdar & Karimian, 2019).

The fact that several remaining qanats, like Mehrgerd, are still draining groundwater without any maintenance for decades, added to the proven inefficiency of modern water provision systems to meet water demands in the face of the approaching water crisis, has motivated water sector and urban authorities to embark on qanat rehabilitation projects. However, these efforts are disappointingly doomed to failure when they put their main focus on the physical and technical restoration of qanats, overlooking the participatory conservation and sociocultural aspects of qanats.

In spite of the valuable contributions these researches have made to the sphere of knowledge on qanats, studies that address the challenges that qanat networks face under the pressure of modern-day urbanisation seem to be rare. The majority of available literature is centred around either qanats of rural areas or qanats utilised by the agricultural sector, while there are thousands of kilometres of qanat networks entangled in urban fabrics like Tehran. Many of these qanats are progressively abandoned and degraded because of recent urban developments.

Research Objectives, Method, and Framework

A review of the traditional participatory management systems in Iran, as well as the contemporary community-based interventions (CBI) in the context of qanats, demonstrates the significant role of public participation in this regard. This research aims to provide solutions and recommendations for the enhancement of stakeholder engagement in contemporary qanat rehabilitation practices in Tehran by adapting the traditional communal management techniques and multi-stakeholder approaches to qanat maintenance in Iran. This aim could be translated to the study's main question; How can the traditional community cooperation in qanat management practices be used as a pattern for engaging the present-day overlooked communities, who affect or are affected by qanats' presence, in the contemporary rehabilitation programmes?

To better address this question, we will try to answer the following sub questions:

- How and why have the status of qanats changed in the urban context of Tehran?
- How have these transformations influenced the qanat management practices and stakeholders involved in qanat-related matters?

To answer these questions, the transformation of the key urban water stakeholders from past to contemporary time (Fig. 4) are studied and mapped based on their roles and influence on decision making processes for qanats' management. Primarily, the relevant stakeholders who were typically engaged with qanats' management and exploitation process in the past were identified through a detailed review of available literature and historical accounts. Then, the current state of the management of qanats in the contemporary institutional structure of Tehran's water sector is investigated, so that the present-day central and marginal stakeholders, from public sector, private sector, and civil society are derived based on a review of relevant literature including published articles, a number of unpublished materials, and official policy reports. Additionally, the roles, responsibilities, capacities, and impacts of each stakeholder on qanats' management are identified. The resulting illustration of the stakeholders' networks and the comparative study of the findings not only reveals today's institutional gaps and missing links in qanats' management procedures, but also highlights the former community-based coordination mechanisms that used to support the smooth functioning of qanats in the past.

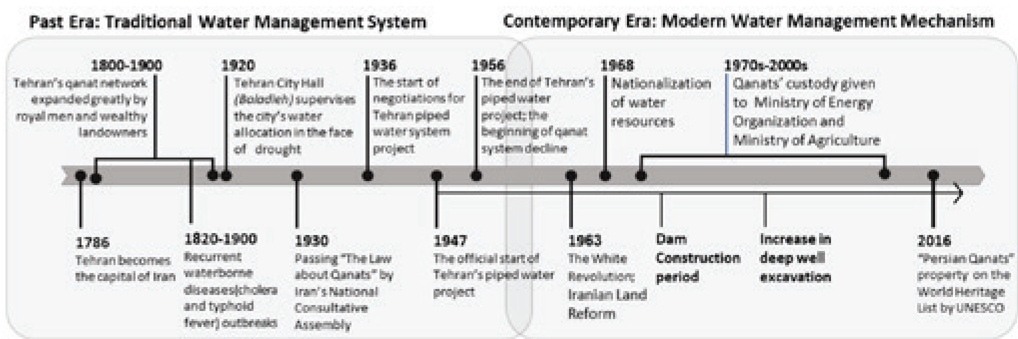

FIGURE 4 Framework of the research (the studied timeframe).

Participatory Management of Qanats in Tehran

The Traditional Qanat Stakeholders

Tehran was merely a small town when it was chosen as the capital of Iran by Agha Mohammad Khan, the king of Qajar dynasty in 1786. Owing to its new prominent position, the small town went through a noticeable population growth that influenced it in many aspects, including citizens' water demand. To meet the city's rising need for new water resources, the government embarked on constructing new qanats in lands that could potentially yield sufficient groundwater resources (Abbasi, 2008, p. 49). Apart from the central government, some wealthy landowners would construct qanats in their own properties, either for benevolent purposes or for making profit by selling extracted water (Ghaffari, 2012, p. 18, 19). Qanat construction was a technical expertise that was held by experienced masters, called *mughannis*, who were appointed by the owners to dredge the qanat galleries and canals from time to time, so that qanats could operate more efficiently.

After a qanat was established, the bigger challenge would arise: how to fairly distribute the water among those who had irrigation rights and lived or worked in the vicinity of qanat outlet. At that time, the only way to regulate water allocation was to implement a turn-based procedure; each group of water consumers, including farms, gardens, businesses, and houses situated in a particular section of the area would be given regular turns, during which water was led to ditches running into their water storage areas (Ghaffari, 2012, p. 44). According to this method, people's turns had to be determined and supervised by a trusted person called *mirab*. Although government once made an attempt to distribute water by means of a clay water pipe (*tambooshe*), the lengthy, serious quarrels over water shares among people, especially in dry seasons, proved the advantages of seeking the help of *mirabs* for fair water division. *Mirabs* were usually trustworthy and active figures of a neighbourhood who were elected by locals. They would allocate qanat water according to a list containing the names of the residents with water rights and the amount of their water shares, as well as dealing with the qanats' financial affairs (Abbasi, 2008; Salek, 2019). Such a time-oriented water distribution mechanism could not impose any limitation on the water consumption rate, which would be an issue during times of water scarcity and drought. This drove Tehran's City Hall (*Baladieh*) to intervene actively and supervise the city's water allocation in 1920 (Abbasi, 2008, p.58-62).

Apart from households and reservoirs as the two major water consumers, there were several businesses that relied on water to operate. Farmers and gardeners, as one of the largest groups of shareholders in the qanats' water, consumed considerable amounts for irrigating their lands and gardens (Abbasi, 2008, p. 60,61). The other two water-dependent business groups were icehouse owners and barrel owners. Since it was common among barrel owners to deceive people into buying low quality ditch water as fresh water from the qanats' outlets, the City Hall took charge of them directly (Abbasi, 2008, p.83,119,120) (Fig. 5). Watermills and bathhouses also depended upon qanat water to provide their service (Semsar Yazdi & Labbaf Khaneiki, 2017, p.145). Water carriers were a fairly small group of people who carried containers in the street in order to sell or distribute water for free (Ghaffari, 2012, p. 39,40). In those decades, qanat water was transferred to houses and water reservoirs via open water channels like streams and ditches that ran through the streets, giving way to a gradual accumulation of pollutants in the water. This led to frequent outbreaks of waterborne diseases which made the Tehran municipality start covering ditches and paving the streets to prevent dust and pollutants from entering the water. Along with the municipality's actions, the government's health department appointed Pasteur Institute of Iran to assess qanats and domestic water quality (Abbasi, 2008, p. 112-117).

FIGURE 5 Queue of barrel owners at Shah Qanat outlet, Old Tehran, 1930s (Kheshtesarekhom, 2018).

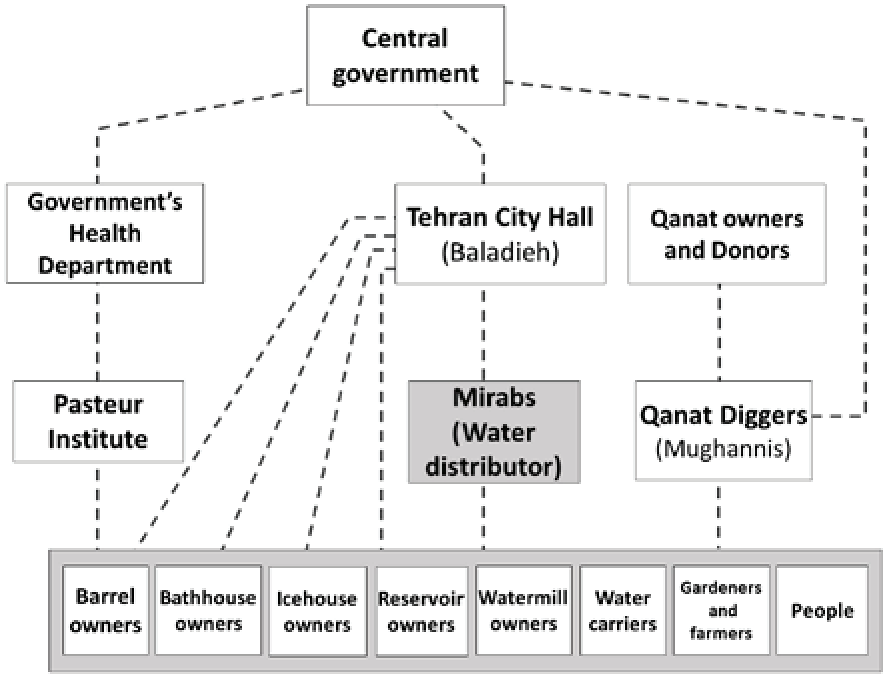

FIGURE 6 Traditional qanat exploitation and management regime.

How influential each of these stakeholders were in the management of qanat systems might have varied throughout city's qanat-dependent lifetime; still, the mechanism shown (Fig. 6 & Table 1) gives an overview of Tehran's traditional water management regime and the parties involved in the process, which functioned effectively for a relatively long period, until the modern time.

The Emergence of the Modern Water Systems

As Tehran was transforming into the flourishing capital of Iran, the modernism movement was thriving in the west, reshaping European cities in an unprecedented way. Witnessing some European governments' enthusiasm in modernising their big cities, Iranian kings and officials showed a tendency for pursuing the same path, and chose Tehran as the flagship of the government's modernisation schemes. At that time, in their memoirs or reports, some foreign travellers and representatives would mention Tehran's primitive infrastructure, especially the polluted, stinking, unsightly ditches (Abbasi, 2008, p.167,168; Ghaffari, 2012, p. 27-29). Such embarrassing accounts, which were damaging to the central government's international pride, became a strong motivation for initiating infrastructure-based developments in the country's water and energy sector during Pahlavi Dynasty (1930s). The transition from the traditional water provision system of qanat towards the piped water system was one of the most significant features of the intended modernisation process. An improvement that took almost two decades, from 1936 to 1956, to be realised, after being halted several times for various reasons, including World War II, economic issues, and political controversies (Abbasi, 2008, p. 142-157). The immediate, easy access to clean drinking water from tap, an age-old dream that had come true through the piped water system, gradually eliminated the past difficulties of supplying clean water for houses from people's memories; despite the fact that they were still living in a mostly arid country with high chances of facing water crises, wasting water became a common act, especially among younger generations.

TABLE 1 Qanat water exploitation and management stakeholders in the past, from late 18th to mid-20th century.

SECTOR	STAKEHOLDER	WAYS OF INVOLVEMENT	REFERENCE
Public sector	Central Government	Constructing qanats	(Abbasi, 2008)
	Tehran City Hall	Supervising qanat water allocation, controlling urban water supply, quality assurance for drinking water, supervising barrel owners' activity	(Abbasi, 2008)
	Government's Health Department	Dealing with the issue of water pollution	(Abbasi, 2008)
	Pasteur Institute	Assessing qanat water and domestic water quality	(Abbasi, 2008)
Private Sector	Barrell owners	Supplying and selling high quality qanats water (under city hall's supervision)	(Abbasi, 2008; Ghaffari, 2012)
	Bathhouse owners	Collecting water for providing public hygiene services (under city hall's supervision)	(Abbasi, 2008)
	Reservoir owners	Collecting water for public consumption	(Ghaffari, 2012)
	Icehouse owners	Collecting and use of water for producing ice (under city hall's supervision)	(Abbasi, 2008)
	Watermill owners	Using qanats' hydropower for grinding grains	(Semsar Yazdi & Labbaf Khaneiki, 2017)
	Gardeners and farmers	Using water for irrigating their lands and gardens	(Abbasi, 2008)
Civil Society	Mirabs	Allocating water shares to irrigation right owners	(Ghaffari, 2012)
	People	Using water for domestic purposes	(Ghaffari, 2012)
	Qanat owners and donors	Funding qanat construction	(Ghaffari, 2012)
	Water carriers	Selling or distributing water for free in their containers	(Ghaffari, 2012)

A similar transition occurred in the agricultural sector's water provision mechanism on a national scale. Before Iranian Land Reform in the '50s and '60s, landowners were the owners of qanats as well, so they were responsible for maintenance and repair of qanats if needed. But, with the implementation of the land reform programme and redistribution of lands from large landowners to smaller agricultural workers, the custody of qanats was given to multiple owners, a situation that resulted in the mismanagement or dereliction of qanats (Maleki & Khorsandi Aghaei, 2006, p. 47,48). The fact that qanats were extended over a vast geographical area beneath several lands with different owners, sometimes became a source of conflict among qanat owners and landowners. As a consequence, National Consultative Assembly of Iran passed a law on qanats, in an attempt to determine legal considerations and limits of construction, development, and exploitation of qanat systems. However, landowners preferred to dig deep wells in their own lands in order to avoid such controversies. Digging these deep wells without conducting previous hydrological assessments led to a gradual decrease in the groundwater level and the complete drying up of nearby qanats (Maleki & Khorsandi Aghaei, 2006, p. 44).

Along with these two fundamental changes, there were several other factors that more or less contributed to the gradual decline of qanats systems. Dams that were constructed across rivers from the 60's onwards reduced the supply of water that fed Tehran's peripheral plains, leading to a constant reduction in the amount of underground water, resulting in many qanats starting to dry up. Coupled with declining subsurface water levels, the uncontrolled process of urbanisation severely damaged qanat networks.

Many qanat channels and shaft wells got ruined while excavations were carried out for motorway or high-rise construction projects. Lack of attention to the paths of existing qanat networks and their buffer zones by the officials in Tehran's metro tunnels construction project destroyed many of them over the past three decades. To worsen the situation, the leakage of sewage from domestic wastewater collection wells into the qanat channels deteriorated many qanats' water quality (Maleki & Khorsandi Aghaei, 2006, p.47-49).
In terms of management and exploitation, the numerous laws and legislations concerning qanats and groundwater throughout the past century not only resulted in a heightened complexity of bureaucratic procedures, but also diminished people's role in the preservation and exploitation of qanats. This plurality in the management and ownership of qanats, and the multiple laws concerning this system, have given rise to bureaucratic complexity, inconsistency between different sets of laws, and conflict among key stakeholders in qanat exploitation and maintenance.
All these transformations that have taken place over the last 70 years have brought about several new forces and considerations that influence the qanat system's existence and function. As a consequence, the categories and interrelationships of stakeholders involved in contemporary qanat exploitation and management regimes dramatically differ from those of the past.

The Contemporary Water Governance System

Over the past decades, owing to the reliance of consumers on piped water systems, new qanats have been rarely constructed, and qanat-related activities have become limited to their exploitation, maintenance, and rehabilitation. As the country's water sector has gone through dramatic changes over the past decades, partly due to laws and legislations that introduced water resources as public assets, a considerable share of authorisation and responsibilities concerning qanat construction, maintenance, and rehabilitation was assigned to two major public organisations: Ministry of Energy and Ministry of Agriculture *Jihad* (Ministry of Agriculture (*Jihad*) Act, 2001; Ministry of Energy Organization Act, 1975; Nationalization of Water Resources Act, 1968). Nowadays, Ministry of Energy stands at the top of the hierarchy of power, occupying the most influential role in the decision-making processes relating to qanats. The ministry's mandates for qanat preservation and management include conducting benefit assessment and feasibility study for the construction of new qanats or dredging and rehabilitation of existing ones, issuing excavation permits, verification of competency for *mughannis*, resolving the conflicts among qanat beneficiaries and adjacent qanat owners, determining qanats' buffer zones, and delegating some of the aforementioned responsibilities to its subordinates. Furthermore, according to the law, Ministry of Energy has the authority to take the possession of qanats that have been abandoned for more than four years. The regional water company branches, as the main subordinates of Ministry of Energy, are entrusted with issuing excavation and dredging permits for qanats in their respective provinces. Alongside Ministry of Energy, and at the same time under its authorisation, the Ministry of Agriculture *Jihad* is responsible for qanats that are utilised for agricultural purposes. Because of the increasing complications arising from the arguments over ownership of qanats, Real Estate Registration Organisation is in charge of drafting ownership documents and determining the owners' property rights (Fair Water Distribution Act, 1983).
Currently, the most important beneficiary of the majority of active qanats in Tehran is the city's Gardens and Green Spaces Organisation, which, under the authorisation of Tehran Municipality, uses qanat water for irrigating urban green spaces (Shoaei, 2018). This puts Tehran municipality under the obligation to preserve and maintain qanats, not only as their current owner but also as a major organisation with a wide range of authorities. Ministry of Energy and Tehran's city council have put an emphasis on the municipality's obligations concerning qanats (Fair Water Distribution Act, 1983). In addition to its direct responsibilities for qanats, Tehran municipality influences qanats within the city indirectly through some subordinate organisations, such as Waterways and Qanats Department, Disaster Mitigation and Management Organisation, and Department of Environment and Sustainable Development. These organisations are assigned to do diverse tasks, including identification and mapping of existing qanats

networks, managing qanat water consumption, protecting qanats from pollution or destruction, and mitigating the threats of land subsidence due to the destruction of qanats ("Saze-haye Hayatbakhshe dar Hale Ehtezar [Vital Structures at Stake]," 2019; Shoaei, 2018; "Naghshe-ye Bi-khasiat az Qanavat-e Tehran [Useless Maps of Tehran's Qanats]," 2018).

Apart from Tehran municipality, there are still some qanats that are owned by individuals. in such cases the owners are in charge of all the expenses and implementations needed for the repair, dredging, and rehabilitation of their qanats, although they have to obtain required permits for these practices (Fair Water Distribution Act, 1983).

FIGURE 7 Participants of World Heritage Volunteers Camp 2017 doing preservation activities for Hasanabad-e Moshir Qanat, Mehriz ("Bargozari-e dovomin camp-e davtalabane-ye UNESCO dar Iran [Holding the second UNESCO Volunteers Camp in Iran]", 2017).

Local qanat knowledge had a mostly empirical basis in the past, so qanat-related studies were rare and usually conducted by foreign scholars. However, nowadays, the qanat is regarded as a valuable feature of Iranian cultural heritage. Hence, many institutions and research centres encourage carrying out studies on qanats from various perspectives, from socio-cultural to technical (Fig. 7). Over the past a few decades many researchers and university students have conducted studies in order to achieve the best ideas and practical solutions for the efficient rehabilitation and protection of existing qanats. Together, this community of researchers and scholars form a new type of actor named "the academia". Alongside the Department of Environment and Sustainable Development of Tehran municipality, the academia supports the improvement of qanat knowledge.

The challenging coexistence of qanat systems and contemporary urban elements had generated overlapping responsibilities or conflicts of interests between the stakeholders of present qanat water management regimes (Ministry of Agriculture (*Jihad*) Act, 2001) (Fig. 8 & Table 2).

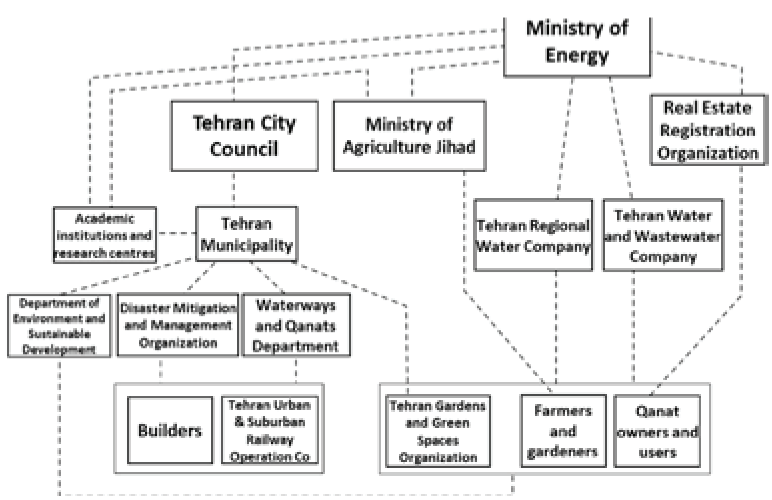

FIGURE 8 Contemporary qanat exploitation and management regime.

TABLE 2 Present qanat water exploitation and management stakeholders.

SECTOR	STAKEHOLDER	WAYS OF INVOLVEMENT	REFERENCE
Public sector	Ministry of Energy	Protecting and supervising qanats, issuing permits for construction of new qanats or dredging and rehabilitation of existing ones, issuing excavation permits, verification of competency for diggers, determining qanats buffer zones, requiring owners to dredge or rehabilitate qanats	(*Fair Water Distribution Act*, 1983; Ministry of Energy Organization Act, 1975; Nationalization of Water Resources Act, 1968)
	Ministry of Agriculture Jihad	Protecting and supervising qanats which are utilized for agricultural purposes, especially qanats situated outside city boundaries (alongside ministry of energy)	(*Fair Water Distribution Act*, 1983)
	Tehran Regional Water Company	Issuing qanats dredging and repair permit (under supervision of ministry of energy)	(*Fair Water Distribution Act*, 1983; Shoaei, 2018)
	Tehran Water and Wastewater Company	Preventing from leakage of urban sewage into qanat water	(*Fair Water Distribution Act*, 1983)
	Real Estate Registration Organization	Drafting qanat ownership documents and resolving controversies surrounding qanats (under the supervision of Ministry of energy and Judicial system of Iran)	(*Fair Water Distribution Act*, 1983; Nationalization of Water Resources Act, 1968)
	Tehran City Council	Pushing through legislation on protection of urban qanats, requiring the municipality to take needed actions	(*Fair Water Distribution Act*, 1983; Shoaei, 2018)
	Tehran Municipality	Protecting and maintaining qanats within the city boundaries (the main beneficiary of qanat water), Identifying qanat networks and obliging other organizations and private sector builders to respect their buffers	(*Fair Water Distribution Act*, 1983; "Naghshe-ye Bi-khasiat az Qanavat-e Tehran [Useless Maps of Tehran's Qanats]," 2018; Shoaei, 2018)
	Tehran Gardens and Green Spaces Organization	Using qanat water for irrigating urban green spaces	(Shoaei, 2018)
	Waterways and Qanats Department	Protecting qanat networks against urban construction and excavation projects	("Saze-haye Hayatbakhshe dar Hale Ehtezar [Vital Structures at Stake]," 2019)
	Disaster Mitigation and Management Organization	Preparing qanat network maps for other organizations' inquiry	("Naghshe-ye Bi-khasiat az Qanavat-e Tehran [Useless Maps of Tehran's Qanats]," 2018)
	Department of Environment and Sustainable Development	Gathering information about qanats, using new methods and techniques of planning and managing activities and interrelationships concerning qanats, optimizing qanat water consumption, preventing qanat water pollution, supporting researches on qanat rehabilitation and protection	(Hashemi, 2007)
	Tehran Urban & Suburban Railway Operation Co	Considering qanat networks and paths in the design and construction of tunnels	("Vaghti Qanat-ha Zir-e Pa-ye Tehran ra Khali Mikonand [When Qanats Cause Land Subsidence in Tehran]," 2018)
Private Sector	Builders	Considering and respecting qanat paths and buffer zones in construction projects	(Shoaei, 2018)
	Farmers and gardeners	Using qanat water for irrigating their agricultural fields and gardens	-
Civil Society	Qanat owners and users	Dredging and repairing qanats	-
	Academic institutions and research centres	Conducting researches on qanats	-

Key Findings and Discussion

According to Hussain et al. (2008), the functioning of the qanat systems is dependent upon three types of factors: physical, environmental, and socio-cultural (p. 343). This classification was used as a basis for summarising challenges that Tehran's qanat networks deal with (Table 3 and Table 4). When compared, the two different time frames reveal a noticeable change in two main aspects of qanat life: first, the kind of challenges that the qanat network has faced over the past century, from common operational issues to the problems that stem from the inharmonious coexistence of qanats and urban development products; second, the number and socio-occupational status of the stakeholders involved in the process.

TABLE 3 Qanat challenges in the past and stakeholders who were involved in addressing the issues.

	PHYSICAL			ENVIRONMENTAL		SOCIO-CULTURAL		
	Repair and Dredging	Qanat network Damages and destructions due to urbanization	Land subsidence due to qanat tunnels destruction	Decrease in groundwater level	Water pollution due to wastewater seepage	Conflicts over ownership and water rights	Costs of repair and maintenance	Heritage preservation
Ministry of Energy	√	√		√	√			
Ministry of Agriculture Jihad	√	√		√	√	√	√	
Tehran Regional Water Company	√			√			√	
Tehran Water and Wastewater Company					√		√	
Real Estate Registration Organization								
Tehran City Council		√					√	√
Tehran Municipality		√					√	√
Tehran Gardens and Green Spaces Organization								
Waterways and Qanats Department	√	√	√		√		√	√
Disaster Mitigation and Management Organization		√	√					
Department of Environment and Sustainable Development			√	√	√			
Tehran Urban & Suburban Railway Operation Co		√	√					
Builders		√				√		
Farmers and gardeners					√			
Qanat owners and users	√				√			
Academic institutions and research centers	√	√	√	√	√			√

Evidently, the number and diversity of qanat users has decreased over time. This is partly due to the disappearance of several traditional businesses like icehouses. Replacement of qanats with piped water systems and deep wells is another reason for the limited numbers of remaining users. This shift has led to a decrease in the influence of civil society on decisions made in relation to qanats. According to Hussain et al. (2008), the proper functioning of the qanat relied on social factors of cohesion in community, participation, cultural values, and community leadership, combined with technical interventions. However, with the downturn in community presence and influence, qanat-related activities converted from a participatory action into a technical intervention on the part of the small groups of remaining users.

A comparison of the two qanat governance regimes indicates another important result: the challenges this traditional system encounters currently is predominantly addressed by governmental organisations, whereas in the old times it was the community who played a more effective part in solving the problems. As an example, *mirab* was one of the most influential players of the past who has totally disappeared over the years. With a multifaceted role, *mirabs* used to make a significant contribution to the smooth operation of qanats before the modern era. Apart from supervising the water share division and rational water consumption, they were held accountable for settling water-related disputes and administering the qanats' budgets. But, in their absence in the contemporary qanat management regime, those responsibilities seem to be distributed among the governmental bodies (Ministry of Energy, Ministry of Agriculture *Jihad*, Tehran City Council, and their subordinates). This change has brought about a big drawback: the omission of a facilitator of communication and a mediator between community members and formal institutions, which has become a vast gap between the qanat-related community and the authorities. Without such an actor, neither governors nor authorities would notice the real-life problems and conditions that qanats may experience or cause. In addition, the people who affect or are affected by the presence of qanats cannot properly express their demands.

TABLE 4 Contemporary qanat challenges and stakeholders who are involved in addressing the issue.

	PHYSICAL		ENVIRONMENTAL		SOCIO-CULTURAL		
	Construction	Repair and dredging	Decrease in water level	Water pollution	Distribution challenges	Disputes over water share	Costs of qanat maintenance and repair
Central Government	√						
Tehran City Hall			√	√	√	√	√
Government's Health Department				√			
Pasteur Institute				√			
Barrell owners		√		√			√
Bathhouse owners		√		√			√
Reservoir owners		√		√			√
Icehouse owners		√		√			√
Watermill owners		√					√
Gardeners and farmers		√					√
Mirabs		√	√		√	√	√
Households		√		√			√
Qanat owners and donors	√				√	√	
Water carriers		√		√			√
Qanat diggers	√	√	√				

The present-day highly bureaucratic qanat management system, which excludes stakeholders from civil society in the problem-solving processes and interventions, has not been particularly successful so far. As an example, over the past decades several organisations and institutions have been directly appointed by the central government to deal with the issue of qanat destruction during urban construction projects (namely Waterways and Qanats Department, Disaster Mitigation and Management Organisation, and Department of Environment and Sustainable Development), yet none of these bodies has been able to effectively tackle this problem. This is mainly because when multiple organisations are in charge of the same issue, instead of reaching a consensus over the actions and plans needed, they either come into conflicts, or pass that responsibility onto one another to avoid complications that might arise. Unfortunately, this ignorance has caused many qanat channels and galleries to get destroyed by excavation projects. Salek (2019) argues that while a centralised water management regime turns out to be incapable of solving such conflicts effectively, a participatory, community-based water governance style will make way for more hands-on solutions.

However, as we can see, these transformations have not always ended up with eliminating the part of civil society actors. Among the multiple new governmental organisations that have been established or got involved in qanat's matters, there is a new party from civil society with a considerable influence in the realm of qanat knowledge. With its reliance on science and knowledge, "the academia" has an extensive capacity to take part in diverse qanat challenges. As qanats' status has shifted from the city's most fundamental water infrastructure to a technical legacy of past generations, some new types of qanat-related interventions have emerged, termed as preservation and rehabilitation activities. Even though most of the preservation activities are planned and performed by governmental bodies, the academia plays a role in this particular domain.

The academia has the potential to make remarkable contributions to almost all aspects of the qanat's life, through raising awareness about the heritage values of the qanat and its capabilities for mitigating the urban water crisis, and providing technical consultancy services and working out novel ideas to better adapt the qanat system to the modern-day urban context. Owing to their respected position among the public and their ability to effectively liaise with governmental organisations and authorities, this party is also the best group from which the missing valuable actors of the past could be recreated in the form of multidisciplinary committees.

Conclusion

The interconnection between the present-day Tehran's urban life and its existing qanat networks is really challenging on account of the threats they pose to each other. On the other hand, qanats can bring added value to their urban context not just because of their heritage value, but for their potential in mitigating the upcoming water crisis. Qanat rehabilitation programmes that have been implemented have so far proved ineffective, for they focus solely on the physical maintenance of qanats and neglect the vital role of community participation in the process. This confirms that qanats will not be revitalised unless there is a social mobilisation and willingness for its revival among the community.

The qanat's background in shaping particular cooperation among community members could be a useful starting point for recreating those participatory patterns. However, under the present circumstances and dramatic transformations that have occurred in Tehran's socio-environmental realm, those patterns are not applicable unless they are adapted the changing needs and uncertainties caused by urbanisation process, demographic growth, and climate change.

Therefore, through a comparison of the traditional qanat management practices and the involved key actors' interrelations, with the contemporary management regime, this research tried to discover the gaps that hinder the sustainable rehabilitation of qanat networks. Rather than the common limited focus on physical aspects, this study demonstrated the increasingly widespread and complex social, cultural, environmental, and political challenges in water regime of Tehran with an emphasis on a broader appreciation of community engagement processes in urban water management. The insights from this comparison provide a grounding for further research on how actors and institutions from the public sector, the private sectors, and particularly the civil societies and local communities interact in planning, governing, and inhabiting the built environment.

Further research into participatory qanat rehabilitation in Iran is still required—in particular in the area of stakeholder engagement and a coordination mechanism for the water management sector in Iran, including traditional water infrastructures. Moreover, a greater degree of integration between interrelated stakeholders from public and private sectors, as well as civil societies, is needed to effectively synthesise the socio-economic and environmental challenges within these endangered qanat systems. As such, this research is both an attempt to study participatory approaches to qanat rehabilitation in Iran from past to present and an invitation for future collaboration to put this knowledge into practice on the ground.

References

Abbasi, E. (2008). *Abname-ye Tehran [Tehran Water Notes]* (pp. 49-157). Tehran: Cultural Research Bureau.

Aghazadeh, S. (2013). Sustainable Water Use of Qanat Based on Economy and Culture. *Recent Advances in Energy, Environment and Sustainable Development*. (pp. 144–147).

Bargozari-e Dovomin Camp-e Davtalabane-ye UNESCO dar Iran [Holding The Second UNESCO Volunteers Camp in Iran]. (2017, September 10). Retrieved from https://www.isna.ir/news/96061911013/

Bonine, M. (1996). Qanats and Rural Societies: Sustainable Agriculture and Irrigation. Cultures in Contemporary Iran. In J.B. Mabry (Ed.), *Canals and Communities: Small-Scale Irrigation Systems* (pp. 183–209). University of Arizona Press.

English, P. (1998). Qanats and Life worlds on Iranian Plateau Villages. In: J. Albert, M. Bernhardsson, R. Kenna (Eds.), T*ransformation of Middle Eastern Natural Environment. Bulletin Series 103.* Yale School of Forestry and Environmental Studies (pp. 187-205). Yale University Press.

Daneshmir, R., & Spiridonoff, C. (2012). Subterranean landscape: The far-reaching influence of the underground qanat network in ancient and present-day Iran. *Architectural Design*, 82(3), 62–69. https://doi.org/10.1002/ad.1405

Estaji, H. & Raith, K. (2016). The Role of Qanat and Irrigation Networks in the Process of City Formation and Evolution in the Central Plateau of Iran, the Case of Sabzevar. In Arefian F., Moeini S. (Eds.). *Urban Change in Iran.* The Urban Book Series (pp. 153–169). https://doi.org/10.1007/978-3-319-26115-7

Fair Water Distribution Act. (1983). Retrieved from https://rc.majlis.ir/fa/law/show/90679

Ghaffari, E. B. (2012). *Seda-ye Pa-ye Ab [The story of drinking water in Tehran]* (pp. 18-44). Tehran: Nashreshahr.

Hashemi, H. S. (2007, November 25). Qanats, Ganjine-ye Nashenakhteh-ye Ab-e Tehran [Qanats, Tehran's Obscure Treasure]. *Jamejam Online*. Retrieved from http://jamejamonline.ir/online/669847805344196459

Hussain,I., Abu-Rizaiza, O.S., Habib, M., & Ashfaq, M. (2008). Revitalizing a traditional dryland water supply system: the karezes in Afghanistan, Iran, Pakistan and the Kingdom of Saudi Arabia. *Water International.* 33:3 (pp. 333-349).

Kheshtesarekhom. (2018, May 1). Slidehaii az Avakher-e Dahe-ye 30- Ab-e Ashamidani-e Tehran [Some Slides from Late 30s- Drinking Water of Tehran]. Retrieved from https://kheshtesarekhom.wordpress.com

Labbaf Khaneiki, M. (2018). Qanat and territorial cooperation in Iran, Case study: Qanat of Hasan Abad, Yazd. *Water History* (pp. 185–206). Springer

Maleki, A. & Khorsandi Aghaei, A. (2006). *Qanat in Iran, The Case Study Of Tehran Qanats.* Tehran: Sherkat-e Pardazesh va Barnamehrizi Shahri.

Ministry of Agriculture (Jihad) Act. , Pub. L. No. 1–534 (2001).

Ministry of Energy Organization Act. , Pub. L. No. 2520 (1975).

Naghshe-ye Bi-khasiat az Qanavat-e Tehran [Useless Maps of Tehran's Qanats]. (2018, October 20). Donya-e-Eqtesad. Retrieved from https://www.donya-e-eqtesad.com/fa/tiny/news-3287576

Nationalization of Water Resources Act. , Pub. L. No. 124–1578 (1968).

Qanat. (n.d.). In Wikipedia. Retrieved February 18, 2020, from https://en.wikipedia.org/wiki/Qanat

Salek, A. (2019). Rediscovering Community Participation in Persian Qanats: An Actor-Network Framework. *European Journal of Creative Practices in Cities and Landscapes (CPCL)*, 2 (1). (pp. 153-172). Department of Architecture, University of Bologna.

Saze-haye Hayatbakhshe dar Hale Ehtezar [Vital Structures at Stake]. (2019, July 24). *Hamshahri Online*. Retrieved from /www.hamshahri-online.ir/news/448825/

Semsar Yazdi, A. A. (2014). *Qanat of Zarch.* Yazd: ICQHS

Semsar Yazdi, A. A., & Labbaf Khaneiki, M. (2017). *Qanat Knowledge* (pp. 145). Dordrecht: Springer.

Shiraazi, K., Milani, M. A., Sadeghi, A., Azami, E., & Azami, A. (2012). Qanat (Subterranean Canal) Role in Traditional Cities and Settlements Formation of Hot-Arid Regions of Iran. *World Academy of Science, Engineering and Technology,* 6(67), 385–390.

Spooner, B. (1974). City and river in Iran: Urbanization and irrigation of the Iranian plateau. *Iranian Studies*, 7(3–4), 681–713. https://doi.org/10.1080/00210867408701484

Shoaei, S. (2018, June 25). Chahi ke Baraye Khoshk Shodan-e Qanat-haye Tehran Kandeh Shod [Wells That Caused the Drying of Tehran's Qanats]. *Irna.* Retrieved from www.irna.ir/news/82952572/

Vaghti Qanat-ha Zir-e Pa-ye Tehran ra Khali Mikonand [When Qanats Cause Land Subsidence in Tehran]. (2018, October 15). *Irna.* Retrieved from plus.irna.ir/news/83514193/

Wessels, J. (2005). Reviving Ancient Water Tunnels in the Desert, Digging for Gold?. *Journal of Mountain Science*, 2 (4). (pp. 294-305). Science Press.

Wessels, J. & Hoogeveen, R.J.A (2002). Renovation of Qanats in Syria. In Z. Adeel (Ed.), *Sustainable Management of Marginal Drylands, Application of Indigenous Knowledge for Coastal Drylands* (pp. 1-13)

Zivdar, N., & Karimian, A. (2019). Integrative Conservation of Tehran's Oldest Qanat by Employing Historic Urban Landscape Approach. In F. F. Arefian & S. H. I. Moeini (Eds.), *Urban Heritage Along the Silk Roads.* The Urban Book Series (pp. 207–228). Cham: Springer.

Oslo Hydropolis

Transplanting traditional water management techniques into Greater Oslo's urban landscape

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Abstract

Oslo Hydropolis is a running landscape and urbanism design studio at the Oslo School of Architecture and Design that investigates how water can play a socially, ecologically, and economically active role in shaping life in the Oslo region. Historically a water-rich area, weather extremes and seasonal abnormalities question the functionality of cultural landscapes in the Oslo region, which is characterised by rain-fed agriculture in the soils of limited valley areas. Excess and scarcity of water—flood and drought—are exacerbated by the uncertainty of climate change, but even more so by the effects of urbanisation. Population in the Oslo region is growing and new models of how water, urbanisation, and social life integrate have to be defined.

Keywords

landscape architecture, transplant, water management, design methodology, decentralised systems

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To cope with the present challenges, Oslo Hydropolis looks to contexts in which societies have always had to mediate the highs and lows of water. Balancing the seasonal differences and geographical allocation of resources has been a driver of cultural intelligence throughout history. An unmeasurable body of practical knowledge in irrigation and in harvesting, retaining, storing, and distributing fresh or rainwater, exists implicitly as cultural landscapes. It has been made available and developed through research in rural engineering to improve agricultural yields especially in arid climates (e.g. Prinz & Malik 2003). However, as Hein (2020) points out, traditional techniques and heritage landscapes transcend the disciplinary boundaries that in our modern societies divide water into multiple domains. Techniques building on heritage are strikingly integrated, as their intelligence in managing water resources is tied to their aesthetics, place-specificity, and potential to evoke social practices around what often is an open routing of water flows driven by gravity.

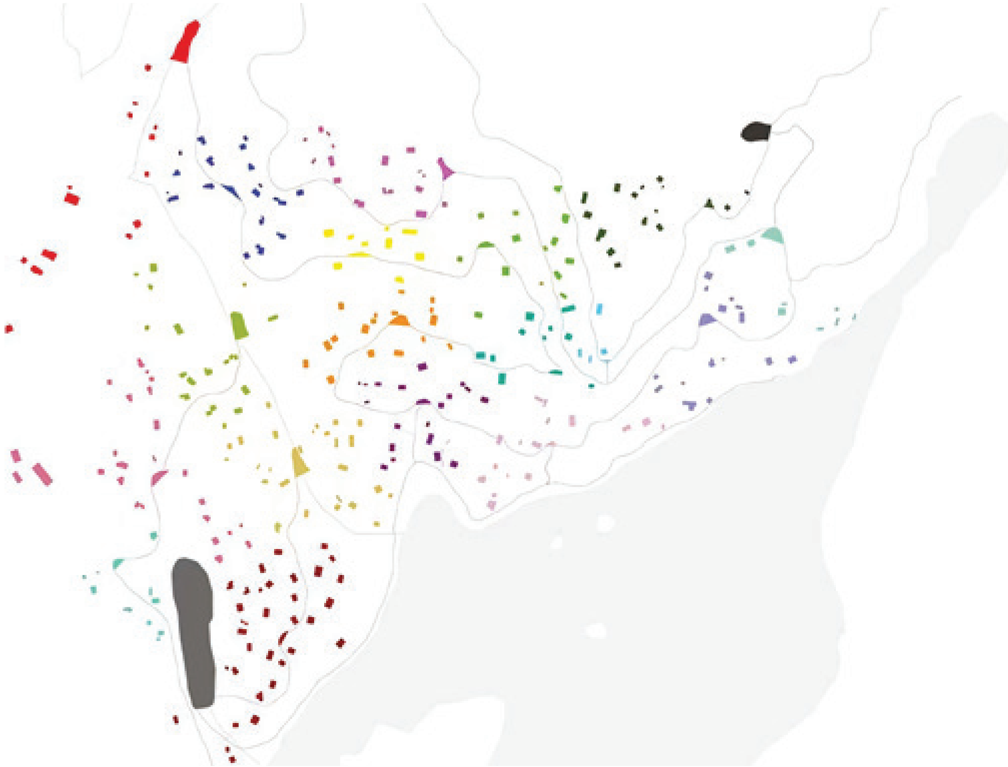
The innovation in the Hydropolis projects lies in the act of *transplanting* these techniques to a different climate and society. *Translating* a technique from the past to the present is a common practice, and contemporary works often reference traditions to anchor interventions adequately in a place and climate (e.g. the park in Saõ Vicente, Madeira, modelled on the historical levadas (Hauswald, 2007)). Teresa Galí-Izard (2006) has added mobility to techniques by isolating them as ideas, allowing many interpretations. Following this track, and conceptually borrowing from the agricultural practice of transplanting, the Hydropolis projects carefully *extract* traditional rural techniques such as run-off agriculture, channelling and damming from their original arid or semi-arid context and introduce them into a very different climate in the Oslo region. Extraction here means to conduct a precedent analysis (Van den Toorn & Guney, 2011) as a way of making implicit design knowledge explicit. The technique's system from source to sink is studied in a three-dimensional flow diagram, in sections to help understand its relationship with topography, and by interpreting the functional elements as a space related to human scale and usage. The transfer is facilitated by a blunt scale comparison and overlay of the original landscape pattern on the new site, followed by a careful adjustment and editing of the transplant to fit the geomorphology, existing patterns of inhabitation, and cultural context.

The following projects are examples from a series of transplants explored within the Hydropolis studios. Two are based in locations where summer cabins are increasingly used throughout the year and the pressure to connect them to the municipal freshwater network is high. The third project is situated in one of the few remaining agricultural areas in greater Oslo. All share a common goal: creating *supplementary systems* that reduce the pressure on the inland reservoirs struggling to quench the thirst of the growing metropolis. However, their ambition extends beyond that, to creating *places* where the harvested water leaves its purely utilitarian purpose and turns into a set of social, recreational spaces. The fine-grained, visible water supply structures that weave into the social realm facilitate greater urban permeability. As devices, the projects bring water to the people but also bring people to the water: to swim, to fish, to skate on the ice, or even to wash clothes.

Transplanting traditional water systems into a contemporary context is a utopian project, both experimental and realistic, that explores the interaction between the geographical base of water and land, and the patterns of inhabitation. Instead of re-inventing the wheel, the projects modify it to better fit the local conditions, changing the tires to match the weather and the terrain.

FIGURE 1 Madeira's open water channels, *levadas*, stem from the irrigation systems introduced to the Portuguese by the Moors. The levadas were built to "walk" water along contour lines from the many springs on the island's northwestern, steep slopes to the drier southeastern side that is more suitable for agriculture. Most of them have paths running alongside them for maintenance purposes, that before roads often provided the only connection from one village to another. The channels' very gentle inclination creates an easily walkable path system and the canopy of leaves that slows down evaporation generates a comfortable microclimate. These qualities have made hiking along levadas a popular outdoor activity.

FIGURE 2 Project Water Walk borrows from the levadas the gently sloping coupling of water and path. Hallangspollen is a popular location of weekend houses off the water grid just south of Oslo. Channels zigzag from the top of the steep hill all the way down to the fjord, harvesting rainwater and bringing it close(r) to the cabins using simply gravity. Introducing waterways simultaneously opens up paths for visiting hikers through the highly privatised area and creates new common spaces: a win-win scenario!



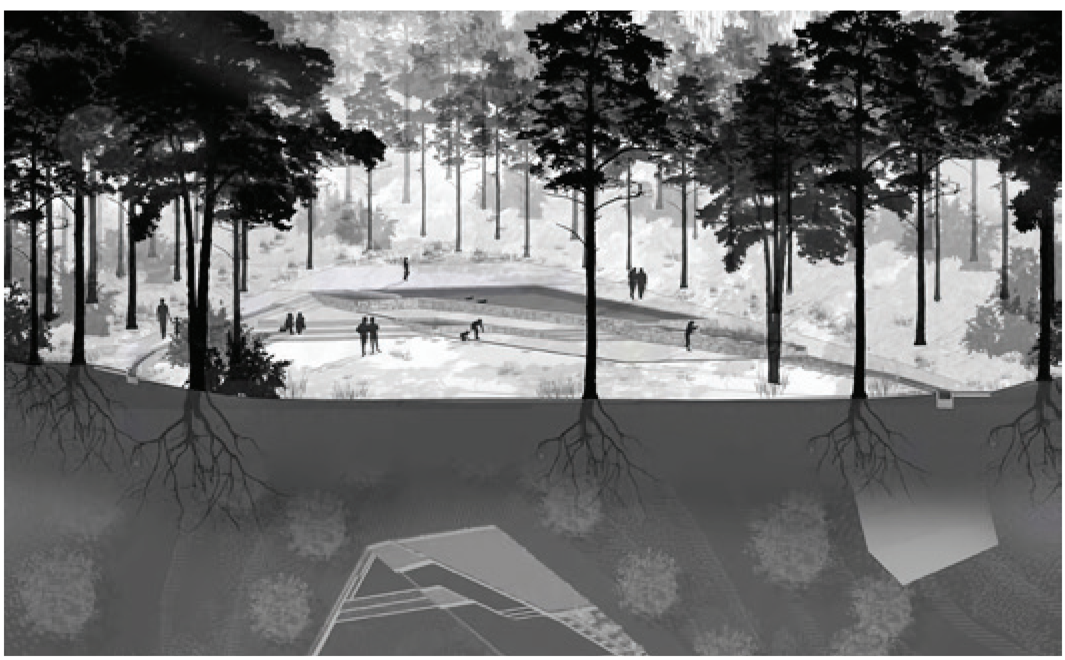


FIGURE 3 Like in many historical precedents, the water network in Hallangspollen provides not only a resource but places for the inhabitants to gather in, socialise or perform household chores such as washing clothes and rugs. The *water foyer* is a clearing around a small dam with household functions. It serves a community of water users, a "neighbourshed", represented on the left by different colours. The new water infrastructure with its community-based water places introduces a new urbanity into the summer cabin culture around the Oslo fjord.

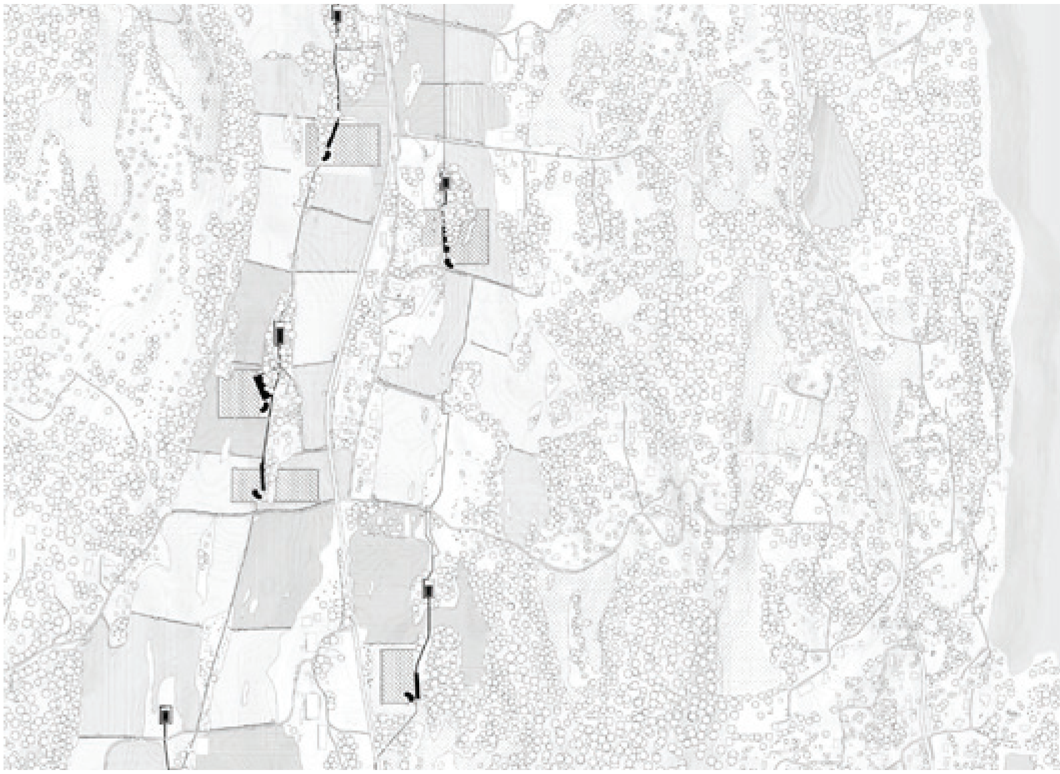
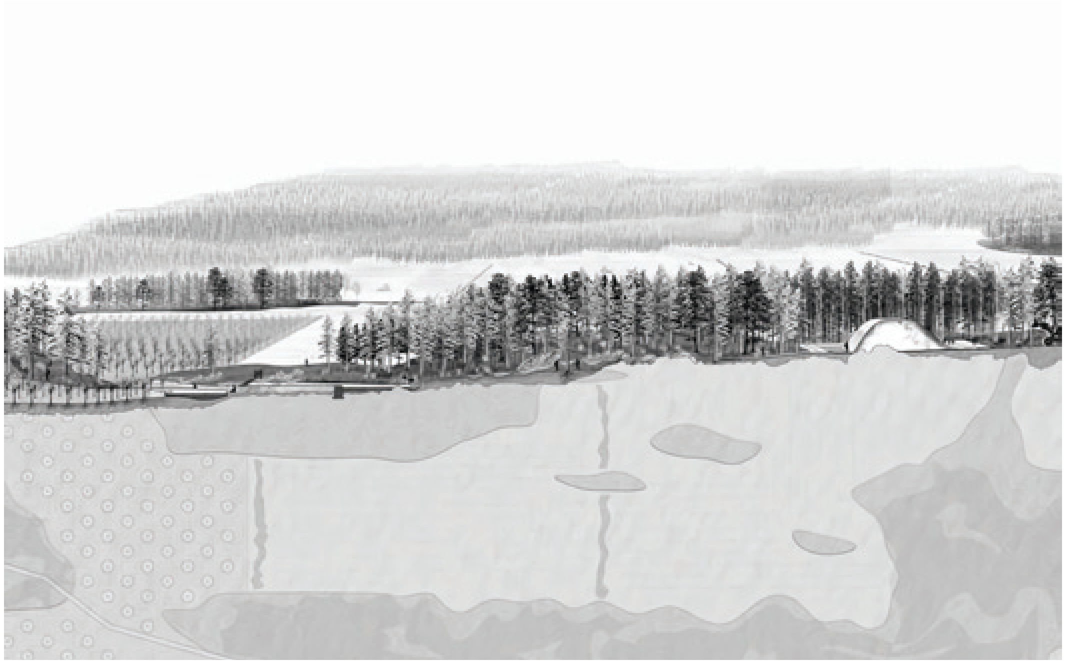


FIGURE 4 Project Melt takes more liberties than Water Walk in interpreting its precedent, the *liman* system in Israel's Negev desert. In the Nesodden peninsula, a recent shift from seasonal to permanent inhabitants and the strong increase in population have pushed residents and farmers to compete for fresh water. Like the two other projects, to offset the strain on the municipal water network Melt leverages precipitation—but in the form of snow. The project develops a snow storing and irrigation prototype that not only responds to a need but seeks to activate Nesodden's agricultural hinterland for higher value horticulture, hikers and cultural events.

FIGURE 5 The liman is a device developed from traditional run-off agriculture in arid climates. It retains water to feed trees that create shaded areas used for stop-overs when driving in the desert. In Melt this is translated into snow collection points and a recreational path network that replicates the limans' way of following road infrastructure.



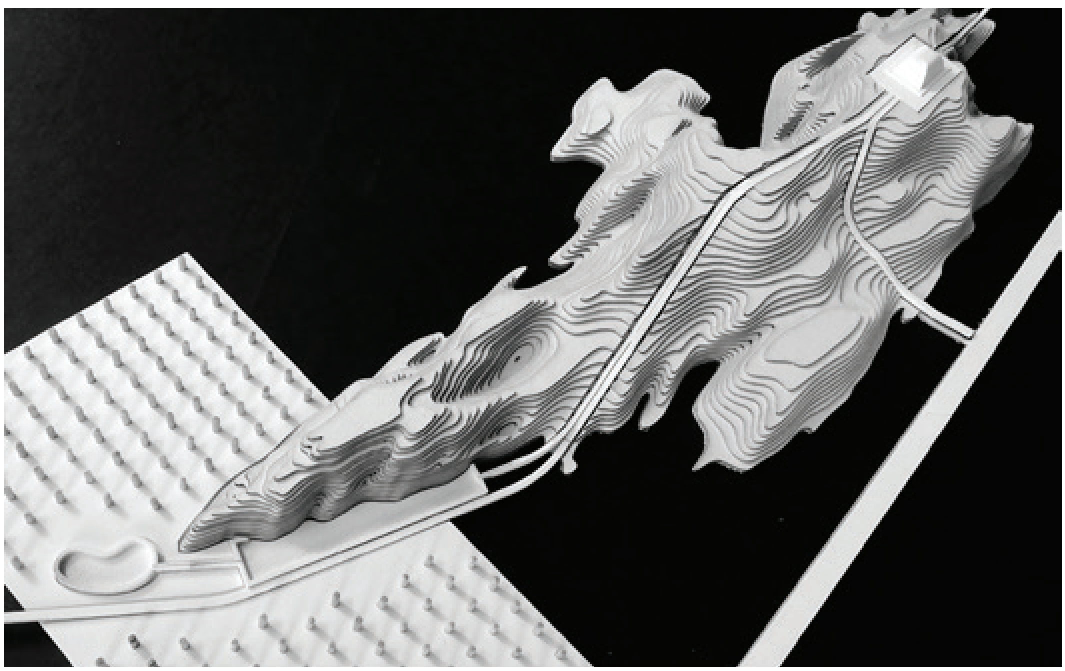


FIGURE 6 Stored and piled on islands of bedrock among agricultural fields, the melting snow trickles into channels instead of infiltrating into the ground. By gravity, the water flows first into a treatment basin and eventu- ally to a retention pond before being used to irrigate orchards. Not only water runs through these spaces and corridors: like Water Walk, Melt uses water as a means to give the public access to areas of the land- scape that were previously inaccessible. The pathways parallel to the channels provide new recreational routes for people to follow in between agricultural fields. In the winter, the white snow mounds become canvases for installations and projections that connect Nesodden's large artist community with a broader resident audience.

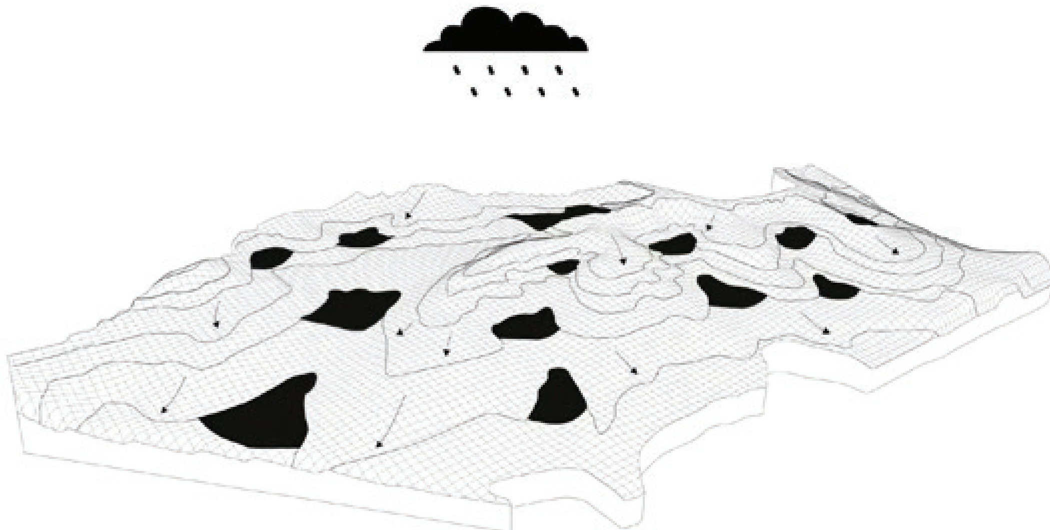


FIGURE 7 Groovy Raindrops draws on the hydrological principles developed by P. A. Yeomans in Australia. To turn dry land into fertile pastures Yeomans experimented with a system he called the Keyline technique which aims at keeping water on site as long as possible, without resorting to terracing. Small ditches dug along contours catch the water that runs off ridges and slopes, and slow it down enough to allow it to infiltrate the soil. The excess is stored in small interrelated dams.

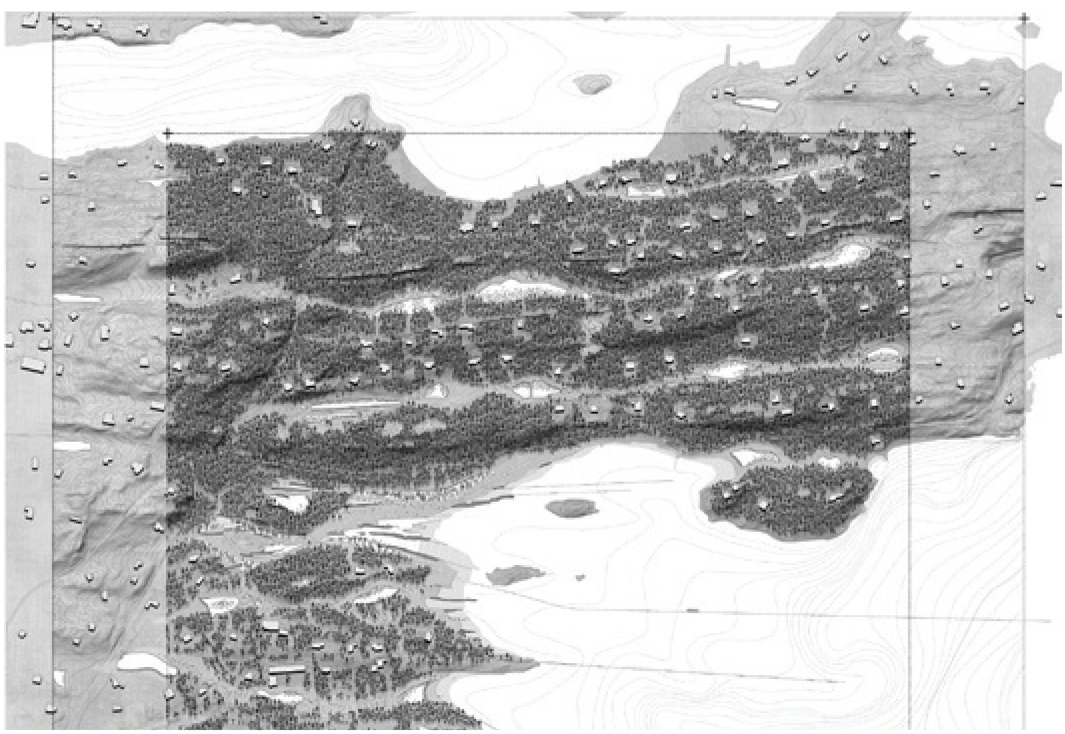


FIGURE 8 The island of Brønnøya is marked by a very specific geology, shallow topsoil and no groundwater. Rainwater runs down from the parallel crests and accumulates at the bottom of narrow, elongated valleys, where it is dammed into dozens of tiny reservoirs through subtle interventions. Much like its precedent, Groovy Raindrops harvests precipitation in wetter times to be used in the increasingly dry months of summer.

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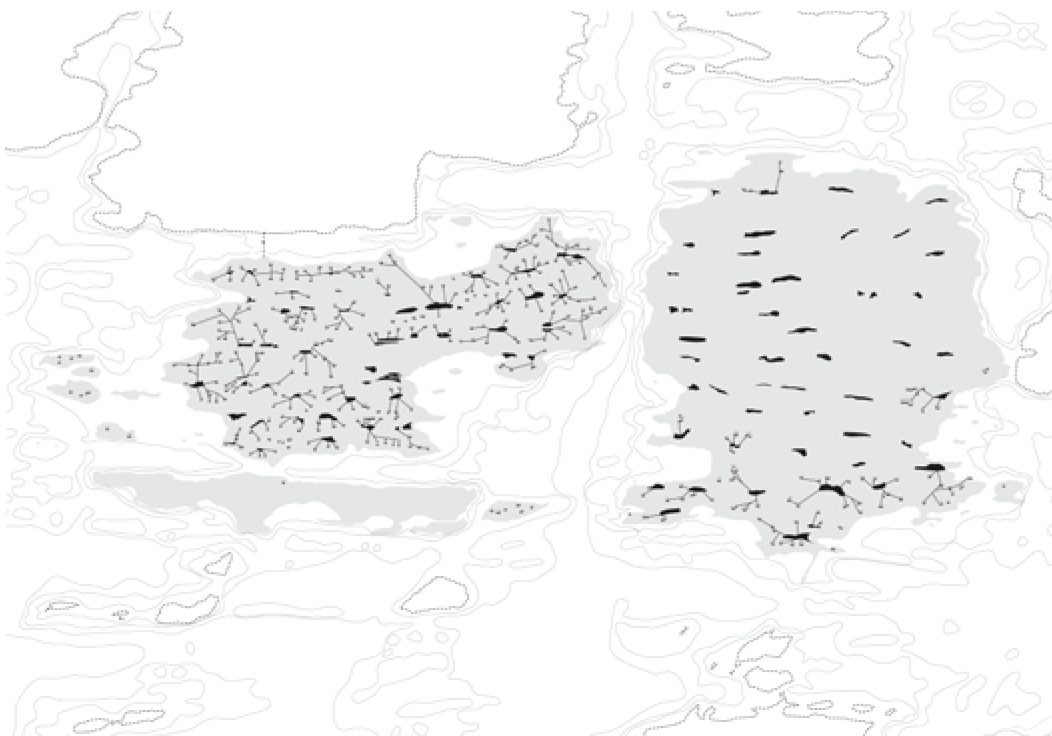

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FIGURE 9 The project proposes a counter strategy to the centralised and piped water system, that serves the island but is at its limits. This strategy introduces a network of small dams distributed between the characteristic ridges like drops of rain on a spiderweb. Using a decentralised alternative where possible reduces strain on the increasingly vulnerable municipal water source and helps guarantee availability to those who don't have other options.

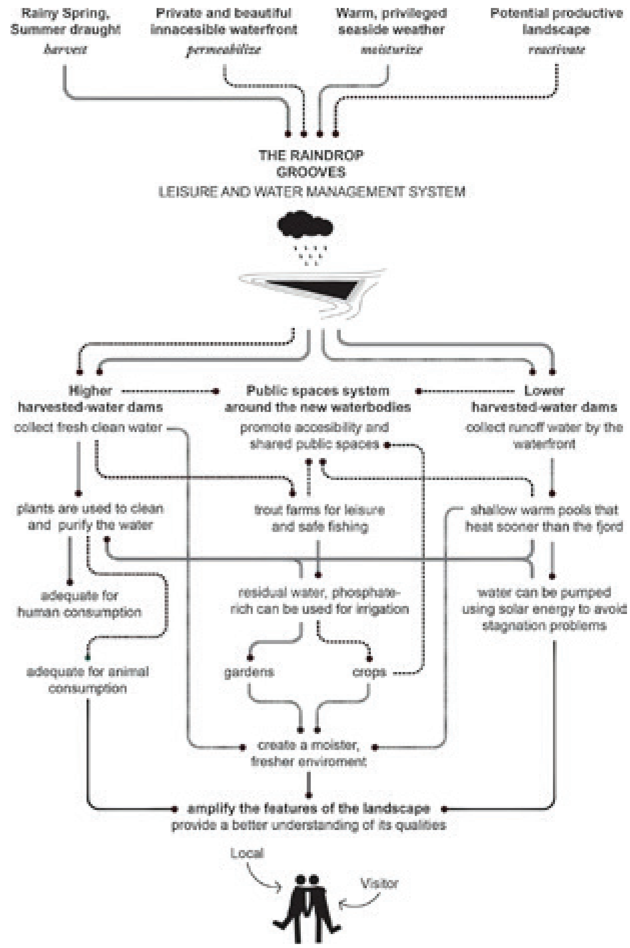

FIGURE 10 Groovy Raindrops strives to create a hybrid system of water management and leisure, taking into account the different social practices around and related to water. The dams are not all the same: they are destined for different uses of water—from utilitarian to recreational to both—and the designs of the spaces reflect these functions.

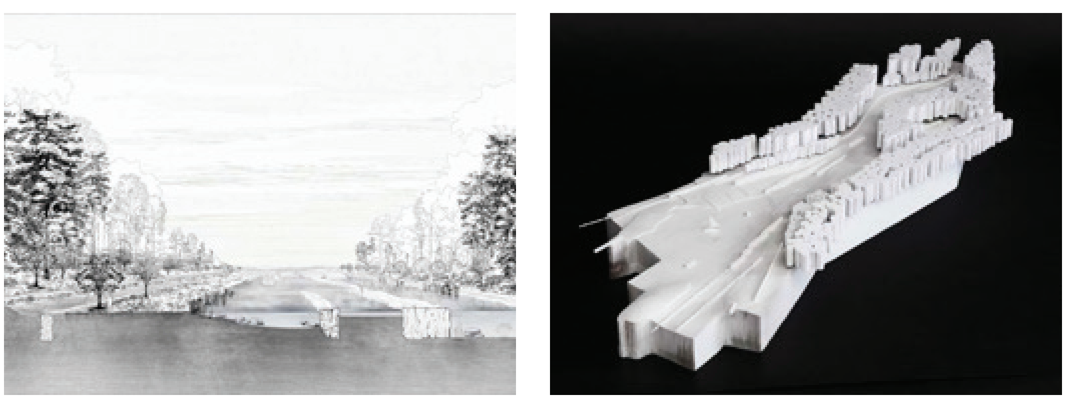

FIGURE 11 On hot summer days, Oslo's inhabitants flee the city to spend time on the waterfront. Some of the dams become extensions of the overcrowded beaches, social spaces wrapped in a cool microclimate. They extend the swimming season earlier in the spring, when the fjord is still too cold to dip in or promote different activities like paddling or recreational fishing.

References

Galí-Izard, T. (2006). *Los mismos paisajes: Ideas e interpretaciones = The same landscapes: Ideas and interpretations.* Barcelona: Gustavo Gili.

Hauswald, K. (2007). Levadas as a Design Principle, in *Topos: European Landscape Magazine. no. 59: 89*.

Hein, C. M. (2020). *Adaptive Strategies for Water Heritage: Past, Present and Future.* Springer.

Prinz, D. & Malik, A. H. (2003). *Runoff farming.* WCA, InfoNET.

Van den Toorn, M. & Guney, A. (2011). *Precedent Analysis in Landscape Architecture, in Search of an Analytical Framework*. TU Delft.

Yeomans, K. B. & Yeomans, P. A. (2008). *Water for every farm: Yeomans Keyline plan.* 4th edition. CreateSpace/Amazon. Retrieved from https://whc.unesco.org/en/tentativelists/6230/