Learning from medieval Italy: urban sustainability concepts from the heritage of hydraulic infrastructures. The cases of Venice, Siena and Bologna

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Abstract

Purpose – Faced with the growing need to find new viable water supply models for urban areas, this article studies and maps the strategies and identifies the key criteria of sustainable development present in pioneering water supply systems in the medieval period. The main aim is to determine which of its innovative principles could be applied in present-day cities.

Design/methodology/approach – From a methodological perspective, two types of cases were established, such as water supply models for human consumption and pre-industrial hydraulic systems, all of which are located in Italy. For the first group, the cases of Venice and Siena were analysed, while for the second, in the context of the cities along the Aemilian Way, the case of Bologna was selected.

Findings – Five key criteria resulted from the analysis of the cases: exploitation, self-sufficiency, maintenance, rationalisation and reuse. The said concepts were defined and contextualised within the framework of the Sustainable Development Goals.

Originality/value – The Middle Ages were a historic moment in technological reinvention, before the development of modern systems of sanitation. With very limited resources, these traditional systems focused on rational use and deep cultural and geographical knowledge. This is why its recognition is of great importance today, in a time full of instabilities, with a view to the work that needs to be done for the development of more sustainable communities.

Keywords Bottini, Campi, Canals, Climate challenge, Cultural heritage, Sustainable development goals, Urban environment, Water management, Waterworks

Paper type Research paper

1. Introduction: water supply and urban sustainability, past and future

In present-day Europe, what one might call the historical cities are the scenarios of history constructed over many centuries. They have witnessed the developments and setbacks of diverse civilisations and constitute a cultural heritage in themselves. Given their varied geography in terms of their relationship with water, there are cities that capture this resource on the one hand, while there are others that have had to bring it to them by means of the

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integration of architecture, urban development and infrastructure over the centuries. To quote Pérez Escolano, “one can deduce the whole history of human settlements from their water supply and sanitation” [1] (Granero Martín, 2002).

In the case of European Mediterranean civilisations, the use of the available water has been directly proportional to their power and economic and cultural development. Following the installation of the first Greek systems based on complementarity (private reservoirs and public networks) and the perfecting, centralisation and monumentality of the Roman systems, the Early Middle Ages were a period of uncertainty. However, the 11th century witnessed a general process of urban growth in western and central Europe, during which ancient Roman settlements were reoccupied and ordered in accordance with Christian values. Churches, monasteries and feudal castles were the cultural and economic centres of the time. The distribution of these cities was regular. They were small and generally one day’s travel from one another. They also had common features, such as city walls and the differentiation of districts by guilds (Norberg-Schulz, 1979). Although they did not reach the size of classical towns and cities, the city made a comeback as a symbol of certain territories.

In this context, water management was once again a key factor in urban development. However, technological limitations, economic difficulties and the instability that characterised this historical period meant that the use of water was far removed from the splendour of former times. The new culture of water in the medieval city was therefore based on its rational use, its security, its exploitation and the maintenance of its facilities. Thanks to these factors, some of these elements of infrastructure continued to supply cities until the early 20th century.

Today, there is once again a need to reflect on the management of this public asset. European cities have advanced systems for collecting, purifying and distributing water, but as other researchers argue, this is a time when water is absolutely dependent on technological models of energy consumption, financial resources and a private and highly competitive market (Marat-Mendes *et al.*, 2016). Furthermore, according to a report by the United Nations, the current processes of urban sprawl will mean that cities will have an additional 2.5 bn inhabitants by 2050 (2018). This scenario means that resource and infrastructure management are among the main challenges facing the city of the future. In the case of cities with a long history, the analysis of their medieval environmental management, as a period in which scarcity was the prevailing fact, may show the way to achieve objectives such as reducing pollution and the environmental impact of contemporary systems (Rugani *et al.*, 2011), shortening supply chains or promoting sustainable mobility. Moreover, past experiences of the rehabilitation of historical infrastructures in capital cities such as Rome or Lima demonstrate how the extension of the useful life of historical infrastructures contributes to energy saving, infrastructural resilience, economic viability and, in short, urban sustainability as well as enhancing the value of their cultural heritage and strengthening their identity (Burkett, 2020).

Because of all of this, the interest of this article consists in the current need to find more sustainable models for cities’ water supply. Its main aim is to analyse several originally medieval water models in Italian cities, in which the infrastructure and systems used were the result of in-depth knowledge of their geography and hydrology and of environmental respect and awareness. Indeed, the urban development decisions that they arrived at are consistent today with contemporary strategies of ecological connectivity and the control of the urban metabolism.

1.1 Related works

The interest in anthropogenic water as an object of research is broad in time and in fields. In the current European context, and particularly in relation to water heritage, the scientific production of Professor Hein of TU Delft and ICOMOS is one of the maximum references in the research topic proposed here (Hein *et al.*, 2023; Hein, 2020, 2023).

However, for the case of this particular methodological approach, focused on the concept of water as an urban installation in medieval Italy, classical research and other formats of dissemination of cultural content have been used as a starting point (Michela, 1842; Costantini, 1984; Guenzi and Poni, 1989; Zaggia, 2004; Kucher, 2005; Baldi, 2006; Angela, 2012; Maldina, 2016; Preziuso *et al.*, n.d.).

Regarding its prospective approach, this paper joins others that have recently shifted the study of historical supply systems to their future contribution facing to the climate challenge (Angelakis *et al.*, 2023; Peters *et al.*, 2021; Šulyová *et al.*, 2021).

2. Materials and methods: the role of waterworks in the medieval planning of Italian cities

In the medieval planning of some Italian cities, the technical development of the Gothic led to the conception of the waterworks as part of the building, the architecture and, in short, of the city. In certain settlements with particular geographical conditions (far from rivers, at a considerable height, etc.), the location, transport and exploitation of water formed part of the urban plan, surpassing the previous strategies of collection for domestic use and surface water capture. In this search for water, design decisions were taken with regard to their buildings and public spaces [2], introducing important innovations in its route.

Among the most innovative medieval cities in the management of this resource, we can differentiate between two groups: those who searched for and channelled water for human consumption and those who domesticated it as a means of development, as a means of transport and travel and used it as a driver of a primitive industrialisation.

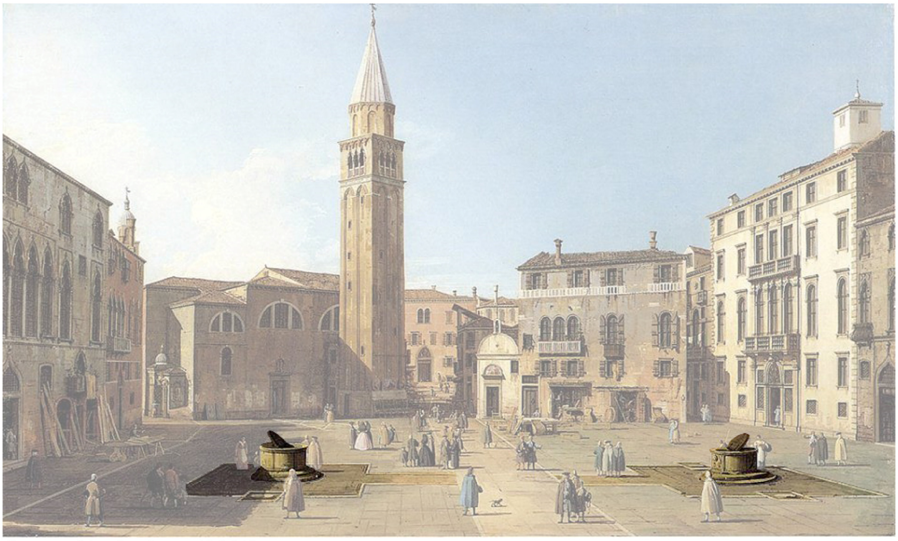
2.1 Water for human consumption

In the first group, we find different systems that responded to the particular geographical features of each region, among which we can highlight two cases. Both enabled the development of two clearly recognisable urban fabrics, where the supply method was an inevitable part of their demographic development in the medieval period.

2.1.1 The case of Venice. In Venice, characterised by its unique artificial nature, its location has meant that the supply of fresh water has been a persistent problem throughout history, requiring a continued technical effort. In fact, this is reflected in its urban layout, which reproduces a version on a large scale of domestic water capture systems (Costantini, 1984).

In urban planning terms, the word *campo* in Venetian refers to an open urban space ringed by buildings. The *campi* [3] (plural), which tradition says spread across a large part of Italy in the medieval period, were laid out next to churches and hosted the market and artisan's stalls. They also included graveyards and were referral social spaces [4]. Whereas in most of Italy they were supplanted by the word *piazza*, in Venice the term *campo* is still in use. There, all of the squares, except the Piazza di San Marco, continue to be called *campi*, *campielli* or *corti*, depending on their size. These Venetian *campi* are also units of urban management, as they were drainage and water storage basins until the arrival of the current systems of supply (Figure 1). The rainwater from the rooftops, streets and surface of the *campo* itself was directed by means of channels, downpipes and slight cambers of the pavement and stored underground, then extracted through a central well (Preziuso *et al.*, n.d.).

As Mario Piana points out, this artificial city had to adapt to the lack of water resources, setting up a system of water collection, storage and supply that was highly unusual in its form and complexity (n.d.). However, these wells also became an infrastructural symbol of the Venetian Republic, and today they can be found in cities such as Zadar in modern-day Croatia (Plate 1).



Source(s): Authors (2023)

Figure 1.
Pozzi as centres of urban life in the 18th century from Canaletto's painting called "Campo Sant'Angelo", 1732

Source(s): Authors (2023)

Plate 1.
Pictures of two *pozzi* today, on the left in a street in Venice (Italy), on the right in the old town of Zadar (Croatia)

What are known as lagoon cisterns, located beneath the piazzas, are filtration-based storage tanks executed in accordance with a technical process that remained unchanged until the late 19th century, when the city's aqueduct was built and this system was rendered obsolete

(Figure 2). The cistern walls were coated with a thick layer of clay, producing an impermeable cladding that separated the collected water from the salt water of the lagoon. The system was also protected on the surface to prevent water from leaking in directly and against *Acqua Alta* [5] (Preziuso *et al.*, n.d.). Cisterns and wells of this kind also call for major maintenance. In fact, their restoration and reconstruction were recurrent throughout the Modern Era and numerous regulations, ordinances and edicts were issued that imposed rational usage of water and also called upon the public not to waste it (Zaggia, 2004). These dual-function piazzas were also the venue for open-air events of a religious and ludic nature, becoming centres of urban life. However, the centralisation of services for the general public undermined their role, which became definitively obsolete at the end of the 19th century, with the construction of the Venice aqueduct. Then, the Venice Council ordered the definitive closure of the wells (Michela, 1842).

The beauty of the workmanship and the materiality of the remaining *pozzi* have made them one of the heritage emblems of the public spaces of the city of Venice. In other words, their constructive and artistic value has made these utilitarian elements transcend their function to become part of the picturesque and unique atmosphere of this city.

2.1.2 The case of Siena. Another form of water supply in the medieval period was that used in Siena. This one is somewhat more complex and comprises several stages. This Tuscan city, the very image of medieval urban planning and Italian Gothic architecture, is located over 300 metres above sea level. It is built on uneven land, on three hills that are joined by a central node. In Siena, the topography has a special relationship with the way in which drinking water is supplied, and hydrology is a determining factor of its urban form. The point where these three sections connect is its beating heart, the Piazza del Campo, a natural basin that gives shape to the main civic space.

Source(s): Georeferenced information from official open data (https://www.atlantedellalaguna.it/), Authors (2023)

Figure 2.
Map of the location of the *pozzi* present in Venice before 1860

Originally, Siena took its water from small streams, as it was a minor settlement. However, in the 12th century, demographic growth led to the search for a new system of supply. The urgent need to guarantee this amenity was expressed in the early 13th century due to three sets of problems. The first of these was firefighting; the second was the use of water for artisanal work such as the processing of wool and leather and finally, the need for drinking water for a growing population (Baldi, 2006).

The second stage in the city's water supply lasted from the 11th to the 14th centuries. Before 1250, its main fountains were built outside the walls, a location that allowed human consumption, their use as fire hydrants, for washing clothes and later as a supply for the paper and iron industries (Figure 3). Located on hill slopes, they were connected to a natural aquifer by a horizontal tunnel, always occupying the low sections of the hills on which the city was situated. Architectonically, the Gothic fountains of Siena are of a very particular type. In themselves, they are facilities of a certain complexity; this geometry protected the water from the elements and, in their day, allowed them to be controlled militarily to ensure they were used appropriately according to certain civic rules and regulations. They were principally divided into three collecting tanks, situated at several heights. The highest, which received the water from the wall, was used for drinking and cooking; the second, which received the overflow from the first, was used as a trough for animals and the third and last level was used as laundry and for artisanal purposes (Baldi, 2006). The city had seven major fountains [6], which still exist today and more than ten on a smaller scale.

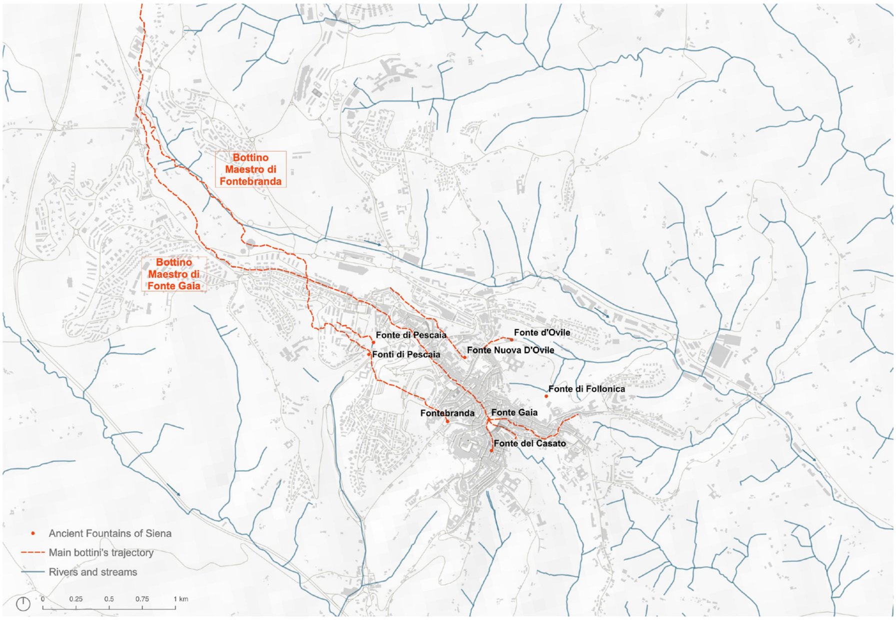
The third stage in the technological development of this city occurred between the 14th and 20th centuries, thanks to the construction of the Bottino Maestro di Fontebranda and the Fonte Gaia (the latter was completed in 1466). Late medieval and modern Siena takes water from several streams to the north-west and channels it through underground galleries with a vaulted section [7], as far as the city centre. At this stage, no horizontal extraction was carried

Source(s): Authors (2021)

Figure 3.
The Medieval fountain as an urban infrastructure in the 18th century from Pecci's stamp "Ristretto delle cose più notabili della città di Siena ad uso de' forestieri ricorretto, e accresciuto", 1759

out. Instead, a veritable underground aqueduct was built (Figure 4). The *bottini* (in plural), in active use until the early 20th century, were ahead of their time and constitute a highly innovative system in the late medieval city. The system used in Siena was not unique, as other cities built on hills used similar elements, but the one followed in Siena is, as Kucher says, a complex and heterogeneous case whose importance resides in its scale (2005). The advanced technology of the *bottini* employed various meanders in the route of the *gorello*, the small channel through which the water ran. This slowed down the rate of flow on an incline by 2‰. Following the courses of ancient Etruscan and Roman ducts, it was the job of the corps of *bottinieri* to maintain them [8]. In the early modern era, water, a scarce and costly resource, was supplied to palaces, monasteries and convents through diversions of the *gorello*. The details of the beneficiaries are still to be found next to the *forellini*, small orifices that measured the derived flow in each case (Angela, 2012). With the arrival of water in the city centre thanks to this system, other fountains were also built, such as the Fonte Gaia (Plate 2) or the Fonte del Casato, both of which date back to the 14th century.

In addition to their undeniable relevance and environmental regulation, the architectural, artistic, typological, technical and urban values of the medieval fountains of Siena are still present today; in fact, they are part of the urban ensemble included in the UNESCO World Heritage List in 1995. On the other side, the *bottini* have been partially reintroduced; they once again water the municipal gardens and supply the monumental fountains. Moreover, in order to safeguard, recover and, in any case, enhance and disseminate knowledge of these underground sites with the respect and attention they deserve, the Cultural Administration of the city allows small, guided groups to visit some of its sections (the Fonte Nuova branch and part of the main Fonte Gaia branch) (Comune di Siena, n.d.). Also in 2010, the Museo dell'Acqua was opened located adjacent to the Fonte di Pescaia. Unfortunately, this water



Note(s): Georeferenced information based on historical cartography
Source(s): Authors 2023

Figure 4.
Map of the main *bottini* and the location of the fountains in the city of Siena

Source(s): Authors (2014)

Plate 2.
Detail picture of the Fonte Gaia and its sculptures, one of the main tourist attractions in the city of Siena (Italy) today

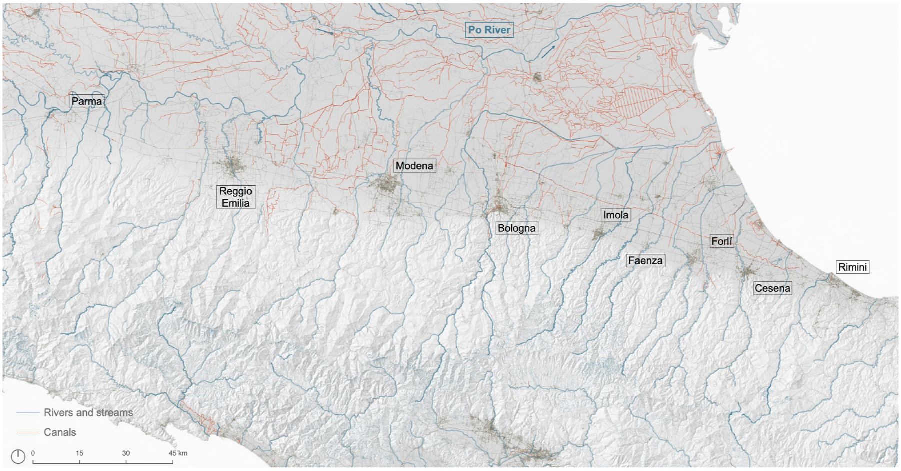
cannot be used for human consumption due to the lack of treatment to deal with the accumulation of calcium carbonate and other pollutants (Angela, 2012).

2.2 Water for industrial use

The second group comprises a number of cities that domesticated water technically, giving rise to one of the leading industrial regions in Southern Europe. Along one of the edges of the Padana Plain, the limit of the Apennines [9], runs a linear system of cities through which the Aemilian Way passes. This regional communications route connects the North of Italy on an East-North-East vector and was conceived by the Romans as part of a territorial plan, as an umbilical cord. To ensure its success, the system had to reach a certain scale and determine the role of each of the cities that comprised it, among them: Rimini, Imola, Bologna, Modena, Reggio, Parma, Fidenza and Piacenza. Along these lines, the Roman centuriation (Roman grid system) laid out a network of roads, water supply and irrigation systems, fields of crops and human settlements. All of this, with time, produced a network of medium-sized cities, constituting the first regional plan in history (Maldina, 2016).

During the Middle Ages, this southern fringe of the Po Valley, formed by cities in a daisy chain, was a major trade route from the Adriatic to continental Europe (Figure 5). Its position on the fringe of the mountain range endowed it with certain hydrographic conditions, due to proximity to numerous torrents, streams and small rivers that crossed the Aemilian Way at right angles. This richness in surface and groundwaters fostered, already from Roman times, the construction of navigable canals that crossed some of the urban centres and ensured its connection with the River Po and the sea. The cases of Parma and Modena are worthy of note, although Bologna is indisputably the most important.

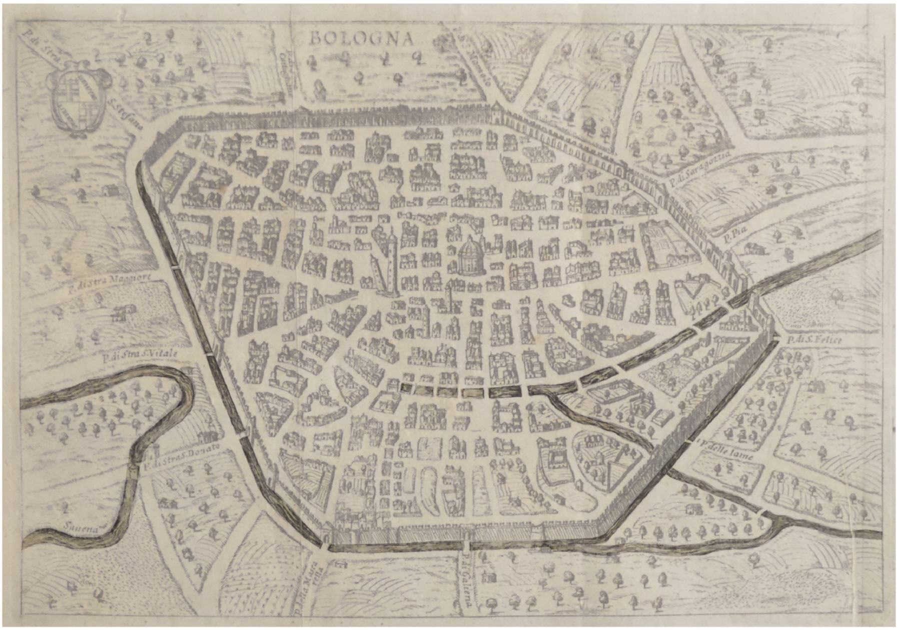
2.2.1 The case of Bologna. This city, with its Etruscan and Gallo-Roman origins, became, from the 12th century on, one of the most important cultural and economic centres in Italy,



Source(s): Authors (2023)

Figure 5.
Map of the Aemilian way, from North-West to South-East, roads and paths show the cities of Parma, Reggio Emilia, Modena, Bologna, Imola, Faenza, Forlí, Cesena and Rímini

thanks to the founding of its university and the work and trade in wool and silk, respectively. Water resources were crucial for its development as a pre-industrial city and its necessary connection with other cities for trade. Between the 12th and 17th centuries, the development of a man-made water system transformed it into one of the leading industrial cities in the West (Figure 6).



Source(s): Authors (2023)

Figure 6.
Water canals Reno and Savena in the 17th century from Schott's map of the city of Bologna, 1650–1700

Bologna is crossed by the river Aposa, which flows seasonally and is located between the Po and the Savena. From the 12th century on, it was colonised by an extensive network of canals that provided waterpower for numerous mills used in the silk industry. Thanks to the construction of the Casalecchio Dam in 1191, located five kilometres from the city, medieval Bologna had over 400 mills. The canals originally formed a moat around the city. Subsequently, they became an intrinsic part of it. As it passed through the city, the Canale Savena was originally occupied by the dyers' guild; the Canale Reno, in its section called Canale delle Moline, was used to generate waterpower to keep the silk mills working and finally, the Canale Navile ran from the port and ensured the connection with the Adriatic via the River Po. For its part, the natural course of the Aposa Torrent was harnessed to perform the role of an artificial drain (Lucci and Ruzzon, 2013).

Thereafter, the silting up of the Canale delle Moline, which followed a traditional layout of waterwheels along its course, led to the design of a new system, the *chiavica*. This was based on the use of a subterranean conduit that distributed the course of the canal by means of sloping channels under the streets and buildings, thanks to the introduction of what was known as the *ruota a casetto* [10]. The kinetic was thus dissipated, so that productivity could be extended throughout the city (Figure 7). These new waterwheels and mills adapted to the new city model, thus sprouting many small factories that apparently did not change the structure of the city or the housing. Thanks to the implementation of this system, in 1591, Bologna had more than 20,000 people engaged in silk production, one-third of its population. The Canale Navile shaped for seven centuries a fast and safe communication route between the city and the North Adriatic to Venice and, from there, towards Northern Europe or the Mediterranean basin (Guenzi and Poni, 1989).

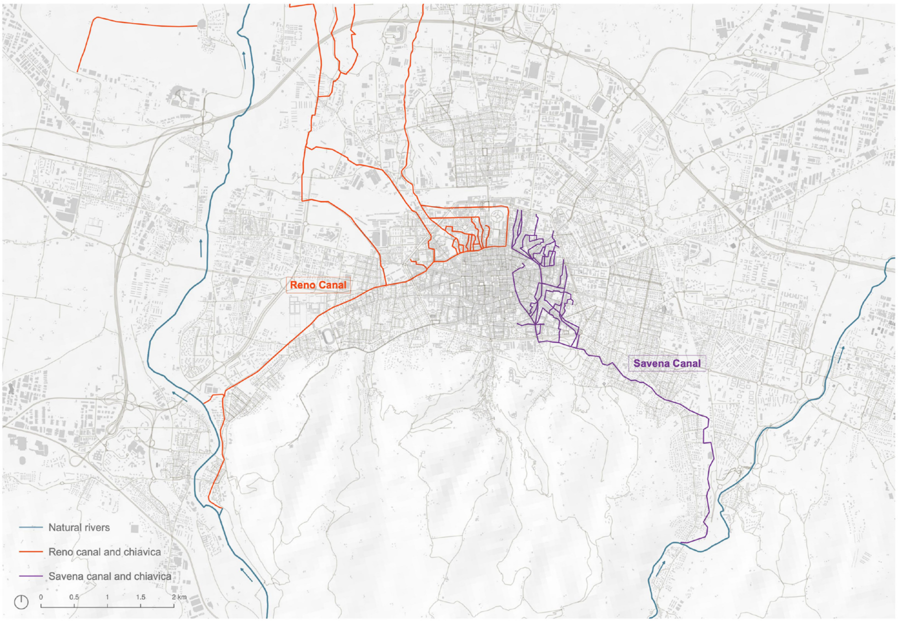


Figure 7. Map of the Reno and Savena canals and their respective *chiavica* within the city of Bologna

Source(s): Georeferenced information from Consortium data (https://www.canalidibologna.it/it/index.php), Authors (2023)

This water-powered industry fed the city until the early 19th century. By then, the construction of new communication routes by land and the connection with Ferrara had made it a fundamentally agricultural territory in view of the decline of the silk and hemp industries. In the 20th century, the canals were progressively covered. However, in recent years, the Bologna Local Government has carried out a valuable work of recovery and improvement, with the restoration of structures and routes (Plate 3), in addition to the creation of the Industrial Heritage Museum. This is evidence of the environmental and cultural value of these assets, which are an indissoluble part of the historic urban landscape of the city and territory of Bologna. In fact, the canals are now part of the territorial landscape plan of the Emilia-Romagna Region.

Furthermore, the presence of the canals is shown on the surface thanks to toponymy. From the merger of the Consortia of the Canals of Reno and Savena, the Canali di Bologna platform emerged. This body ensures the maintenance of the canals and conduits currently used for energy production and agriculture as well as their cultural dissemination (Canali di Bologna, n.d.).

3. Results: key criteria and sustainable development objectives

Today, the difficult hydrological scenario in the southernmost latitudes of Europe is forcing government policies to focus on urban planning that prioritises the rational use of resources

Source(s): Miguel Jiménez Fernández (2021)

Plate 3.
Picture of one of Bologna's canals today

and energy awareness. To this end, the study of the past establishes transfers towards the future (Lap, 2019). The cases analysed are characterised by a series of key criteria, some of which are common, in line with the current requirements laid down by the United Nations in the 17 Sustainable Development Goals and, in particular, with goal number 11 "Sustainable cities and communities". These are:

3.1 Exploitation

The use of rainwater, as reflected in the case of Venice, is today recognised as an intelligent and unselfish supply. This way of collecting atmospheric water reduces energy consumption, shortens supply chains and saves on the use of water from other sources. In many European countries, however, this system was historically relegated to rural areas, where houses sometimes have their own cistern. However, the Venetian case sets a precedent as an urbanscale development of great constructive complexity. Today, countries such as Peru or Portugal are also studying and implementing strategies for the direct reactivation of this type of water heritage, based on the collection of rainwater to deal with droughts, through the reactivation of historic aquifers (Afonso *et al.*, 2019) and infiltration canals (Goodier, 2019).

3.2 Self-sufficiency

The current situation caused by the COVID-19 pandemic has reignited debates about the need for self-sufficiency in neighbourhoods and cities and the vital importance of sanitation. This concept, directly related to urban resilience, is already present in Bologna's industrial model (together with other cities of the Aemilian Way), which bases its industry on available natural resources. This is the kind of energy access that would now be considered a key indicator of urban resilience (Ribeiro and Gonçalves, 2019) as well as the "kilometre zero" water collection approach implemented in Venice.

3.3 Maintenance

The three cases analysed have a lifespan whose beginnings can be traced to between the 11th and 14th centuries and end at the beginning of the 20th century. This means at least five centuries of usefulness and contributes to public awareness of care, since it was possible thanks to numerous and continuous maintenance and conservation works. The evolution of urban water supply to modern sanitation systems has been discontinuous and varied, depending on technical, economic, political and above all, geographical conditions. However, thanks to the work done to maintain them, these systems were not only developed at a time when Western cities no longer had the traditional facilities but also survived and adapted to the technological developments of the modern age (López-Bravo, 2023).

3.4 Rationalisation

Various regulations established the rational use of water, whose waste could be punished severely. The resource was so important that, in cases such as Siena, the fountains were guarded to avoid the misuse of water. This may seem anecdotal today, but in the 21st century, it is translated into the need to educate the population in the knowledge of the territory and its ecosystem resources. Given the urgent need to develop a critical awareness of the spaces we inhabit, the educational work on energy, history, urban and environmental issues carried out by institutions, such as water museums is an example of the functional possibilities that heritage can offer, recovering established geographical relationships between cities and their supply points, between served and served landscapes and helping to tell the story of the history of settlements.

3.5 Reuse

This criterion is reflected in two ideas. Firstly, the architecture of the Sienese fountains that expresses an entire strategy of water reuse through overflows, a system that has become more sophisticated over the centuries and that reveals to users the cycle of water use. Secondly, it is worth highlighting the reuse strategy used in the construction of the three systems analysed, using existing sections of previous infrastructure for their construction.

Undoubtedly, all these techniques could provide ideas for appropriate demand analysis and management, the implementation of drainage systems or the optimisation of rainwater, among other measures mentioned above. In other words, adapting cities to the principles of the Water Wise Cities movement (Rogers *et al.*, 2020) requires knowledge of the territory and the historical management of its natural resources.

4. Conclusions

This research has revealed how the cultural value of these assets resides, in addition to their undeniable historical and architectural legacy, in the environmental opportunity they present to complement the water metabolism in certain cities.

Today, cities must adopt "robust" and "flexible" solutions in the face of hydrological change, meaning those that can deal with predictable situations and those that help to deal with uncertain ones. These solutions include the need to work on: diversification of water sources, reduction of network losses and demand management, mitigation of flooding and direct discharge into river basins through improved stormwater management systems, implementation of sustainable urban drainage systems, decentralisation, protection of aquifers, creation of stormwater pathways and optimisation of stormwater use, creation of urban ephemeral wetlands by flooding parks and gardens, protection of springs outside urban areas, understanding the link between peri-urban agriculture and urban supply, etc. In short, broad understanding of the integral urban water cycle and the care of nearby resources and their availability and flexibility in the face of extreme events.

In relation to the needs of today's metropolises, the cases discussed can provide ideas, solutions, and sectoral improvements to global problems. Thus, the reopening of the canals in Bologna contributes to the environmental recovery of the territory beyond the urban scale. An approach to heritage recovery with environmental objectives has been the protagonist of reflexive processes in recent years in other Italian municipalities, such as Milan (López-Bravo *et al.*, 2021). On the other hand, the assessment, dissemination and reuse of obsolete water distribution systems, such as the *bottini* or the monumental fountains of Siena, support a vision of heritage as a cultural-environmental resource and as a tool for awareness and education. Although these systems do not meet current water use, quality and safety standards, studying them can contribute to the design of more enlightened strategies supported by traditional values and techniques for the future. Furthermore, its reuse constitutes a golden opportunity to supplement the integral urban water cycle, reducing energy consumption and environmental damage derived from certain purification processes, such as desalination.

Finally, the case of Venice is particularly interesting because of its applicability as a complementary sub-system to the general supply systems. This structured, community-based rainwater harvesting system had the particularity of being promoted and managed by the municipality, something that Professor Gentilcore developed in a recent study (2021). This is therefore a universal need (to harness natural resources, increase community self-sufficiency and reduce resource and energy consumption) that is most prevalent in informal peri-urban or rural settlements. Since its implementation is a highly topical research issue (Ali and Sang, 2023; Souto *et al.*, 2022), successful historical examples over centuries such as this one could support government-managed interventions that, with proper investment and maintenance, could be completely safe.

Notes

1. Original quote in Spanish: "del abastecimiento y del saneamiento se deduce toda una historia de los asentamientos".
2. Despite this, sanitation was still a problem that remained to be solved, given the density of some neighbourhoods, the presence of graveyards and black holes and the lack of drainage.
3. These spaces were formerly used for grazing, vegetable gardens or graveyards that were subsequently paved over, hence the term used for them.
4. This was a health hazard, due to the risk of epidemics.
5. High tide.
6. The main fountains are the Fontebranda, the Fonte d'Ovile, the Fonte Nuova d'Ovile, the Fonte di Follonica and the Fonte di Pescaia.
7. The term *boctinus* gave rise to the word *bottini*, probably from the vaulted roof *a botte*, that is, barrel-shaped.
8. Workers who carried out the maintenance and conservation of the sandstone rock tunnels.
9. The Padana Valley follows the course of the River Po, stretching between the Alps and the Apennines and opening to the Adriatic Sea. It is the largest plain in Mediterranean Europe and encompasses part of the present-day regions of Piedmont, Lombardy, Veneto and Emilia-Romagna.
10. This new type of smaller mill, installed inside buildings, generated the movement from the weight of the water instead of from thrust.

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