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A HGIS for the study of waterways: the case of Bologna as ancient city of waters

G Gatta^{1,2} and G Bitelli^{1,3}

¹ DICAM (Department of Civil, Chemical, Environmental and Materials Engineering), University of Bologna, viale Risorgimento 2, 40136 Bologna (Italy)

² Corresponding author; e-mail: giorgia.gatta@unibo.it

³ E-mail: gabriele.bitelli@unibo.it

Abstract. Historical cartography, as a fundamental part of Cultural Heritage, constitutes a precious asset, not only to be safeguarded, but also to be used to study the evolution of the territory over time. In this perspective, regeneration of ancient cartography in digital represents an interesting way to allow new chances of using its historic and geographic information, by modalities that cannot apply to analogue supports. In particular, the creation of HGIS (Historical Geographic Information System) is a way to integrate historical cartography with historical data of various kinds and compare them with the current reality, thus constituting an aid instrument for the study of the historical landscape. The present study investigates the possibility of studying the city of Bologna, in particular its ancient waterways, using some 18th and 19th century maps – georeferenced on the current cartography – together with other archive data (drawings and news taken from an ancient gazette). All these data have been merged in one GIS, this way offering a new look at the ancient city of waters, characterized by a grandiose hydraulic system, with the Savena and the Reno artificial channels and the Aposa natural channel, several silk mills, sewer systems, water wheels and a port.

1. Introduction

There is no doubt that historical cartography is a basic part of Cultural Heritage: firstly it constitutes a precious asset to be safeguarded, and secondly it is a fundamental resource in studying the evolution of the territory over time. In this perspective, regeneration of ancient cartography in digital represents an interesting way to allow new chances, not only to preserve the information content, but also to view and use its historic and geographic information, by modalities that cannot apply to analogue supports.

In particular, the science of Geomatics provides useful work tools to manage historical cartography, including acquisition instruments and methods, georeferencing procedures, tools for the study of the metric fidelity of the maps and GIS (Geographic Information System) procedures for spatial analysis and representation. In particular, the creation of Historical GIS (HGIS) is a way to integrate ancient maps with historical data of various kinds and compare them with the current reality, thus constituting a precious instrument for the study of the historical landscape, as a whole or according to specific issues [1,2].

In this context, a very interesting topic is the study of landscape or urban change [3, 4, 5] associated with historical reconstruction of ancient waterways, and the study on the evolution of industrial complexes for water management (cases of industrial archaeology) in relation with the urban/environmental context [6, 7, 8, 9, 10].

The present study provides an example of the use of geomatic techniques, GIS in particular, for the study of ancient waterways using historical cartography and other archive sources; in particular, it



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investigates the possibility of studying the city of Bologna as ancient city of waters, using some 18th and 19th century maps of Bologna – georeferenced on the current cartography – together with drawings, photos and news taken from ancient gazettes.

2. The city of Bologna at the beginning of the 18th century

Bologna at the beginning of 18th century – a city with 65000-70000 inhabitants [11] – was very different from today in its appearance. Not so much for the buildings in the central core – many of which have remained unchanged until today – but especially for the system of waters.

In fact, until the beginning of the XX century, Bologna was a city of waters, characterized by a grandiose hydraulic system, with three channels (the Savena and the Reno artificial channels and the Aposa natural channel), several silk mills, sewer systems, water wheels and a port. This system had become necessary a few centuries earlier (around the 12th century), when the aqueduct built by the Romans to serve the city – taking drinking water from the Setta river – fell into disrepair, and it had become therefore necessary to build artificial water channels to withdraw water from the two most important rivers that flowed (and still flow) in the city areas: the Savena and the Reno. Over time the water network was completed by numerous other elements, such as channels, drains and diversions of minor water (<https://www.originebologna.com/>).

Today very little of this great water network has remained, but ancient maps of Bologna, together with other archival sources (such as ancient views and news), suitably managed in a GIS environment, are able to give us the image of the ancient city of that time (Figure 1).

3. Materials

In order to reconstruct the ancient water network of the city, with a particular look at the 18th century, some historical maps of Bologna were used [12, 13, 14], together with other archive sources, such as views (drawings, photos) and news taken from ancient gazettes.

3.1. Historical maps

Some historical maps of Bologna – dating back to the 18th and 19th centuries – were used. The maps represent the city inside the third wall perimeter, *i.e.* the part of the city today framed by the boulevards. The first map, drawn by Filippo de' Gnudi in the 1702, is a scenographic map [15]; a detail, showing a channel, is presented in Figure 1. The second one, realized by Monari and Laghi in 1711-12 for technical purposes (the calculation and measurement of the streets to be paved), is the first flat representation of the city, *i.e.* without drawing of the building facades, and is very useful for the study of the ancient place names [16, 17]. Finally, the other maps are part of the Gregorian Cadastre of Bologna, the primary map dating back to just before 1831 and updates dating back to 1873 and 1890-1901, with successive updates until the first years of the 20th century [18].

In order to use the historical maps as a cartographic base in the GIS, a georeferencing process was performed; it is the process of assigning object coordinates, in a modern cartographic system, to the image system, in order to give the digitized historical document a metric content. The maps were georeferenced in the UTM-ED50 reference system, using a high number of Ground Control Points (GCPs), referring to buildings still existent today, selected after a careful research basing on historical documentation related to each building [19]. The modern coordinates were taken from the current large-scale numerical map of Bologna. The geometric transformation used for georeferencing was the second order polynomial transformation. The results of the georeferencing process for the various maps (expressed as total RMSE – Root Mean Squared Error) are summarized in Table 1.



Figure 1. A portion of the map by Filippo de' Gnudi (1702), where bare channels in the city are clearly visible.

Table 1. Approximate scale and georeferencing errors for each analysed historical map.

Map	Approximate scale	N. of GCPs	Total RMSE [m]
<i>Ichnoscenografia</i> (1702)	1:2500	80	10.0
<i>Pianta della città di Bologna</i> (1711-12)	1:1100	180	4.1
Gregorian Cadastre, primary map (ante-1831)	1:1000	>400	1.2
Gregorian Cadastre, 1 st update (1873)	1:1000	>400	0.8
Gregorian Cadastre, 2 nd update (1890-1901)	1:1000	>400	0.8

3.1.1. Vectorization. In order to carry out a specific study on water networks – in particular referring to the 18th century – places, streets and especially waterways were extrapolated from the map dating back to 1711-12, by means of a vectorization process in a GIS environment. Concerning the bare waterways, the objects of interest were recognized on the georeferenced 1711-12 map, and a different colour was assigned to them, to distinguish between the different kinds (rivers, channels, drains, mills, etc.), together with the name that can be read on the map. The use of the 1711-12 map instead of the 1702 map is dictated by its higher level of precision due to the aim for which it was realized. If necessary, the other maps (the Gregorian Cadastre in particular) – co-registered with each other – were used to distinguish between the different kinds of waterways (Figure 2). It is to be highlighted the presence in the place names of many streets which referred (and in many cases still refer today) to water: *Fontanina*, *Molinella*, *via del Porto*, *via Riva di Reno*, *via delle Moline*. This fact denotes the importance of waters in the Bologna of the 18th century.

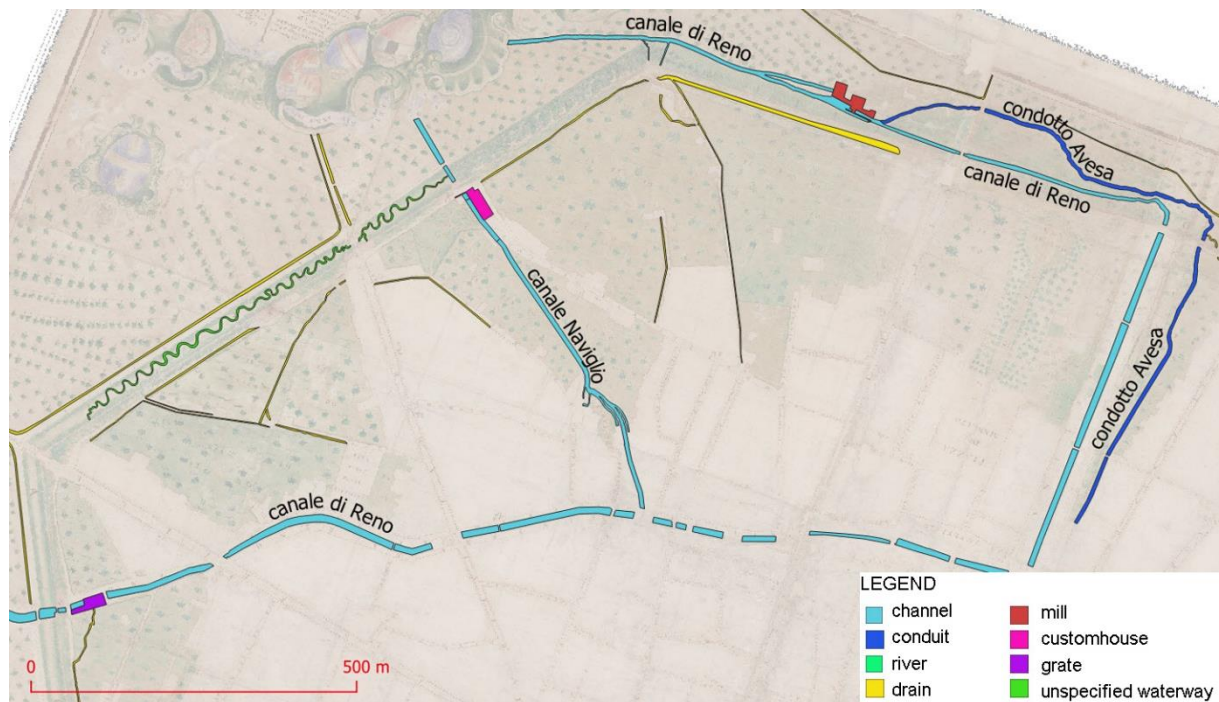


Figure 2. Vectorization of the bare waterways on the 1711-12 map.

3.2. Archive sources

The archive data used together with the historical maps to construct the HGIS were 18th century views of the city and news derived from an ancient gazette, roughly coeval with the 1711-12 map.

3.2.1. Ancient views. A direct view of the ancient city of Bologna is certainly given by many ancient drawings, engravings postcards and photos, made available online by many Bolognese institutions. For the aim of the study, different drawings inherent the waters were collected and, in order to give a direct comparison with today, for each of them a current photo was taken, as far as possible from the same position and with the same direction of sight of the ancient view. As an example, in Figure 3 an ancient view of the paper factories in the Cavadizzo area (today no longer existent) is reported, together with a current photo of the same area.

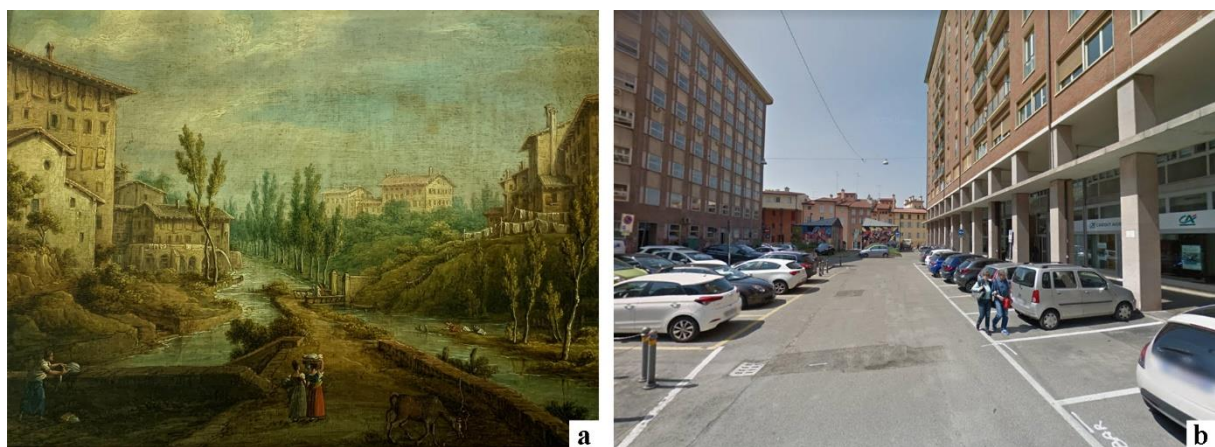


Figure 3. a) An ancient view of the paper factories in the Cavadizzo area (Collezioni d'Arte di Storia della Fondazione Cassa di Risparmio in Bologna – Genus Bononiae, <https://collezioni.genusbononiae.it/products/dettaglio/1398>) and b) a current view of the area.

3.2.2. *Ancient news.* Some ancient news concerning local events were taken from a manuscript gazette of Bologna, named *avvisi*, that circulated at least from the second decade of the 18th century, and was intended for the public [20]. The gazette, collected by A.F. Ghiselli (1634-1730) in his *Memorie antiche manoscritte di Bologna* [21] is today preserved at the University Library of Bologna, and made available online at <https://avvisidibologna.wordpress.com/>. Undoubtedly, the gazette is a priceless source of information, but it has to be considered that the image of the city that appears from it is unavoidably partial, because inherent only a part of the society of that time. For the aim of the present study, some news inherent waters has been selected and georeferenced on the historical maps, basing on the place reported on each news. From the large number of news that deal with the topic of water in various ways (in particular floods) it emerges how important the issue of water was in the Bologna of the 18th century. As an example, a news dating November 5, 1718 is here reported:

L'incessante piovra, continuata venerdì, sabato, e domenica, a cagione della piena dell'Avesa, fece sormontare le sponde di questo canale, alla Fontanina, e nanti Gardino, con non pochi danni alle cantine, e maggiori alle moline, ed al molino fuori di Porta Galliera. Anche il fiume Reno ruppe domenica notte presso la Botta Panfilia.

The incessant rain, which continued on Friday, Saturday, and Sunday, due to the flood of the *Avesa*, caused the overflow of this channel, at *Fontanina* and *nanti Gardino*, with many damages to the cellars, and more to the mills, and to the mill outside *Porta Galliera*. The *Reno* river also broke on Sunday night at *Botta Panfilia*.

4. Construction of the HGIS

The historical maps, once georeferenced and vectorized in the objects of interest, and the archive data, once collected and organized, have been merged in one GIS. The maps constitute the cartographic reference, on the base of which it has been possible to place views and news, by means of vector layers. In particular, concerning the views, for each photo-comparison (between the ancient and the current views) the theoretical viewpoint was recognized on the historical map, and highlighted by a vector point; this way, through each point it is possible to retrieve a photo-comparison, and access the information on the historical image associated to (e.g. kind of image, author, year, place of storage of the original, direction of view) [22]. Concerning the news, they were categorized by location (the name of the river or channel) and time, and collected in a database, which was linked to the vector features extracted from the 1711-12 map. Therefore, the database was linked to the places (waterways in particular) recognized and vectorized on the map by Monari and Laghi, this way associating to the vector elements data extracted from the news [23].

The enrichment of the planimetric representation given by the maps with archive data returns a more realistic image of the ancient city, in particular with reference to the waterways topic (Figure 4).



Figure 4. Screenshots from the HGIS inherent a portion of city in four different years. In 1711-12 and 2020 the vectorization is superimposed to the maps for comparison: the channel mapped in 1711-12 (blue) and the viewpoint of the ancient drawing of Figure 3 (red arrow).

5. Conclusions

The study showed the creation of a HGIS focused on the theme of waters, for the rediscovery of the Bologna in the 18th century, through historical maps – georeferenced in a common modern reference system – and archive sources (drawings and gazettes), located on the maps according to the viewpoint (for the drawings) or the place referring to (for the news).

The GIS allows an intuitive and immediate access to historical maps from the beginning of the 18th century up today, together with images of the city that no longer exist today and news that let us know some aspects of the historical social dynamics, otherwise difficult to understand. It offers a new look at the ancient city of waters, highlighting very clearly the importance that water played for the city only few centuries ago. Combining different kind of data, the GIS environment results a useful tool for the study of the evolution of the city and the rediscovery of its history, for research purposes as well as tourism promotion purposes.

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