Conference Proceedings 2019

issn 2459-3893

Editors
Chrysoula Boutoura
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Evangelos Livieratos

14th Conference of the International Cartographic Association Commission on Cartographic Heritage into the Digital

DIGITAL APPROACHES TO CARTO-GRAPHIC HERITAGE

Thessaloniki

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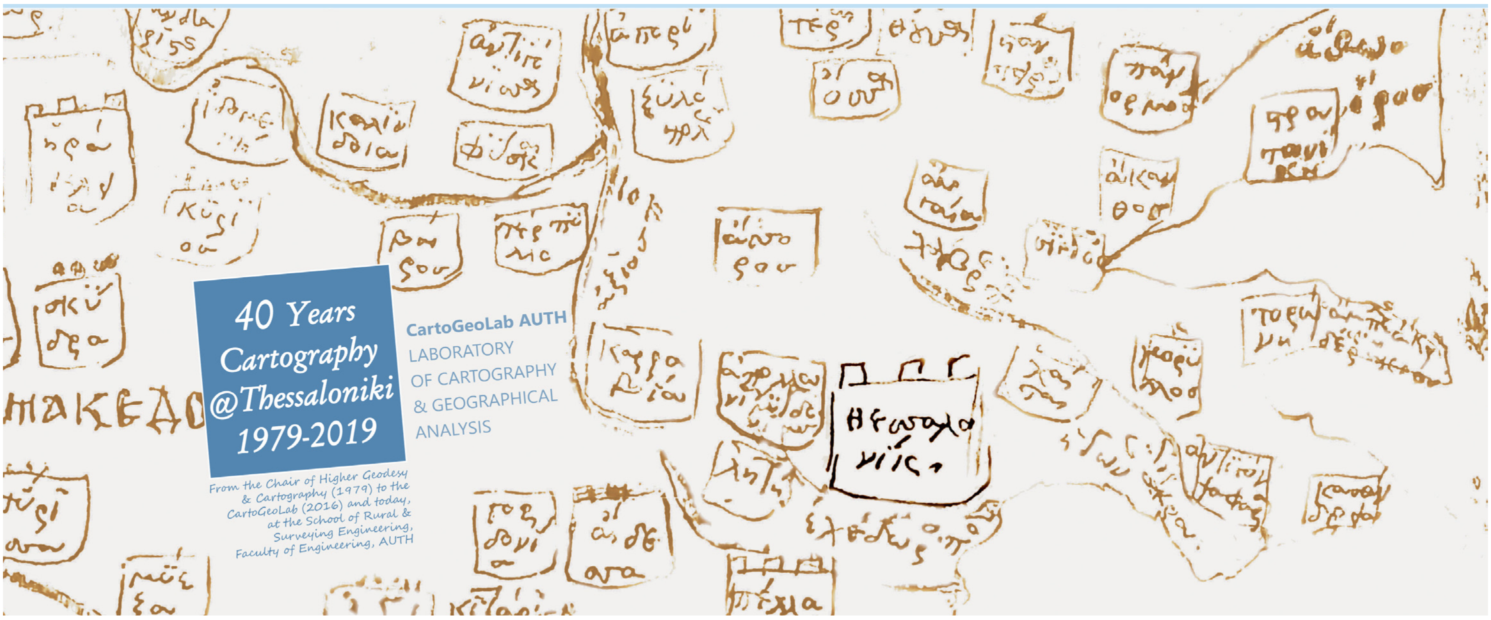

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International Cartographic Association
Commission on Cartographic Heritage into the Digital
Digital Approaches to Cartographic Heritage
Editors: Chrysoula Boutoura, Angeliki Tsorlini, Evangelos Livieratos
Proceedings
14th ICA Conference *Digital Approaches to Cartographic Heritage*
Thessaloniki 8-10 May 2019
Thessaloniki: AUTH CartoGeoLab – ISSN 2459-3893

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The 14th Conference of the series *Digital Approaches to Cartographic Heritage* organised annually, since 2006, by the ICA Commission on Cartographic Heritage into the Digital, is hosted by the AUTH Library & Information Centre and by the Museum of Byzantine Culture of Thessaloniki, on 8-10 May 2019

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The Proceedings

This volume contains the papers presented in the 14th ICA Conference on *Digital Approaches to Cartographic Heritage*, organized by the International Cartographic Association Commission on Cartographic Heritage into the Digital[1], in partnership with the AUTH - Aristotle University of Thessaloniki, supported by the MAGIC - Map & Geoinformation Curators Group.

Following the previous twelve annual Conferences on the *Digital Approaches to Cartographic Heritage* held in Thessaloniki (2006), Athens (2007), Barcelona (2008), Venice (2009), Vienna (2010), The Hague (2011), Barcelona (2012), Rome (2013), Budapest (2014), Corfu (2015), Riga (2016), Venice (2017), Madrid (2018) this 14th Conference continue enriching the literature dedicated to the issue of Cartographic Heritage with special interest for second time reserved to the contribution of Cartographic Heritage to Digital Humanities.

This year's Conference with participation from 21 countries representing 52 institutions (universities, national and university libraries, archives and museums, research institutes, the public and private geospatial sectors, organisations) is organised in eight working sessions dealing with issues related to the ICA Commission and the MAGIC Group terms of reference, namely: digitisation – georeference; cartodiversity content analysis in terms of geometry and thematics; landscape change studies based on map-archival sources; visualisation of cartoheritage, including thematic portals; interconnection of cartographic archival sources, especially map and textual data; historical terrestrial and aerial photography, including photo-related post-cards and relevant material subjects of cartographic parametrisation; cartoheritage web providing issues; interaction of cartoheritage with map and geoinformation curatorship of cartodiversity; development of cartoheritage as a cultural issue, within the context of GLAM, addressed to education and to the general public; geographic affinities with cartoheritage; cartoheritage and Digital Humanities; policy making and strategies for geoinformation / map collection development; metadata models and data-exchange standards for library, archive and museum items; new services and new technologies in geoinformation / map collection; preservation, access and innovation in visualisation and presentation (virtual exhibitions) of cartographic heritage (analogue and digital); integration of other (geo)sources and materials; cooperation with libraries, archives, museums, and partnership with the public and private sectors.

Forty-five papers are included in this Conference Proceedings; from those, twenty-three are published in full-text form and twenty-two represented with summaries, covering a total of 312 pages. The major characteristic of this collection of papers is, as it was in the previous proceedings, the strong *interdisciplinarity* of the issues treated showing the multifaceted content of Cartographic Heritage, especially when embodied into the Digital mainstream. The contributions related to cartography associated GLAM are also numerous proving the relation of cartoheritage with the general domain of Cultural heritage.

The Editors acknowledge the contribution of the Commission Chair Evangelos Livieratos and the Vice-Chairs Carme Montaner and Mátyás Gede and the cooperation of their hosts, the local organisers of the Commission supporting group from the Aristotle University of Thessaloniki, Alexandra Koussoulakou, Katerina Nasta, Angeliki Hatzigeorgiou, Maria Pazarli, Nopi Ploutoglou, Elpida Daniil and the colleagues from the ICA Executive Committee László Zentai, ICA Secretary General and Pilar Sánchez-Ortiz Rodríguez, ICA EC liaison to the Commission, for their support and active participation as well as the members of the Scientific Board and all participants who contributed and attended the Conference.

Chrysoula Boutoura
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Contents

Roberto Ranzi*[1], Matteo Rebuschi*, Fulvio Gentilin*, Matteo Balistrocchi*

Geomorphological changes of the Adige river from the Claricini map (1847) and the impact on flood routing.

Keywords: historical maps, georeferencing, river geomorphology, flood dynamics, dry stone walls

Summary

The topographic map of the Adige river published in 1847 by Leopoldo de Claricini depicting its valley along a 146.2 Km river reach in almost natural conditions was analysed in its metric content. The map in nominal scale 1:20,736 was firstly georeferenced and then some geomorphological parameters (such as sinuosity, anabranching and braiding indexes and river bed width) were measured and compared to those featuring the present condition. Results agree well with a recent study conducted by other authors on a shorter part of the same river reach. Presently, the river geomorphological diversity shows to be far poorer than in the past. The consequences of the observed changes and the impact of river engineering works on flood routing were assessed by hydrodynamic simulations of a critical river reach. The georeferenced ancient river map was also used to identify details of the former landscape, which are definitely lost or are hardly surviving to the strong urbanisation of the floodplains, as dry-stone walls which recently became UNESCO Intangible Cultural Heritage.

Introduction

The technical value for hydraulic and geomorphological analyses of the large scale "Claricini" Adige river historical map, presented in Ranzi & Werth (2016) and Ranzi et al. (2017) is explored in this paper. The river cartography edited by the "Kreisingenieur" and architect Leopoldo de Claricini Dornpacher (1812-1888) in 1847 depicts the Adige river valley, in the Central Italian Alps, from Merano to Borghetto, for a river length of 146.2 km at that time, now shortened to 136.6 km after the river regulation works completed in the XIX century. Old maps of the Adige river dating back to 1805 were analysed by Dai Prà & Mastronunzio (2014) and Mastronunzio & Dai Prà (2016) and recently Scorpio et al. (2018) analysed in detail the river morphology of five georeferenced maps depicting the river before 1893, when the major river channelization works were completed. The river reach they analysed was 115 km long. Here we extend some of the analyses to the entire extension of the river in the Claricini map, thus adding 31.2 km to the analyses. The map was first georeferenced and then analysed with respect to geomorphology. The impact of some channelization works on the flood regime was then investigated by simulating the river routing of three major historical floods under the actual and original levees' conditions. Finally, the importance of the Claricini map for the reconstruction of the mid XIX century road network and the landscape at that time is demonstrated in view of the protection and conservation of the dry-stone walls, which raised in importance after the art of constructing them was named by UNESCO an Intangible Cultural Heritage in January 2019.

Georeferencing the Claricini small scale map.

One of the objectives of geo-referencing the 1:20,736 scale Claricini's map is to compare its the metric content with the current basic topographic map, in order to assess its potential exploitation for research and technical purposes.

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The use of a GIS to superimpose and project information allows professionals and researchers to have a geographic database and a geo-visualization useful to support surveys and analyses on land use and topographical changes over time in different areas: urban, agricultural and river environments. It is also understood that this approach based on the GIS can contribute to the preservation of the landscape and to the protection of an area such as the Adige river, which has undergone dramatic changes in recent decades because of anthropization and is still threatened by new infrastructural projects. For this georeferencing work, the 14 sheets of the small scale 1:20,756 scale "Claricini Tridentina" map (Ranzi et al., 2017) have been projected on the current topographical maps with 1:10.000 scale (CTP, Province Technical Map).
The work of integrating geographical information was carried out by performing a geographic projection using the open-source GIS Quantum software. This allows the user to assign the coordinate reference system (CRS) of the CTP reference map to the historical map by identifying pairs of common Ground Control Points (GCPs) in both.

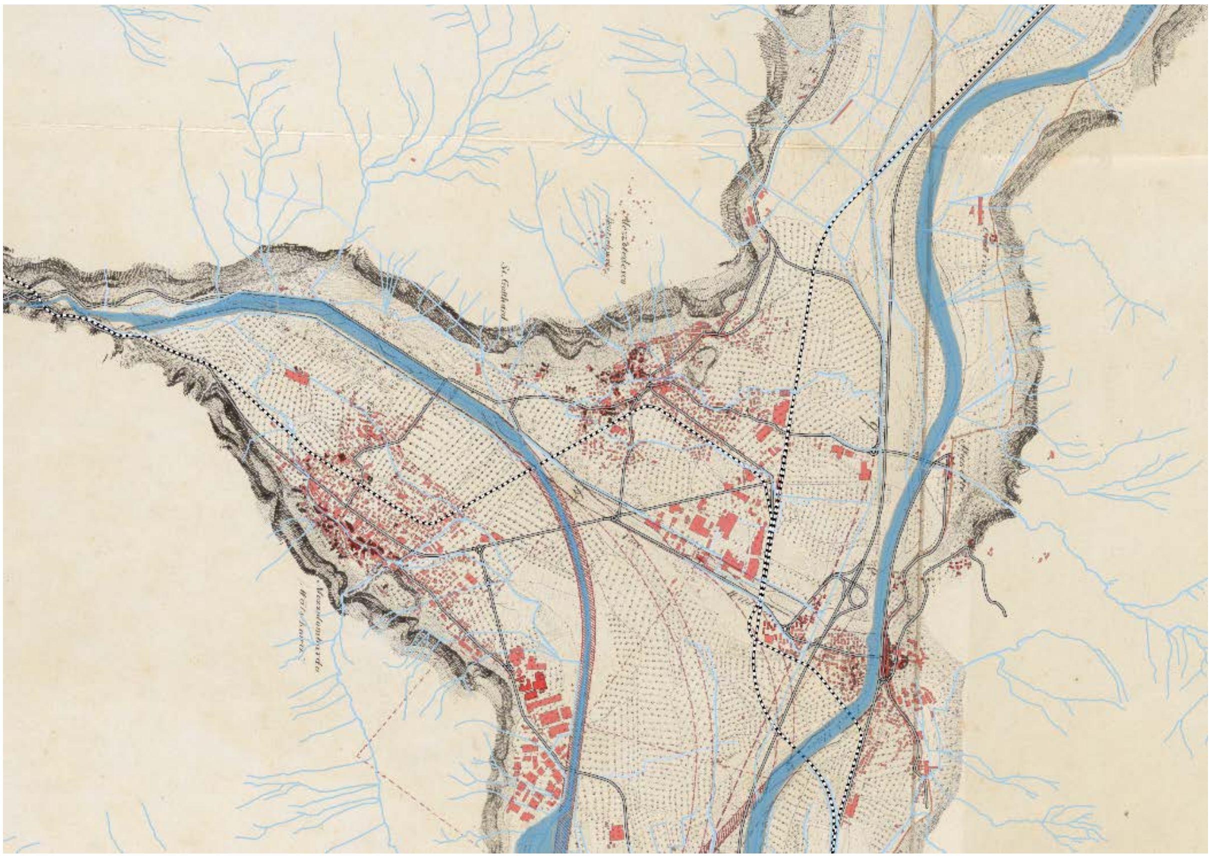

Figure 1: Georeferencing the Claricini map sheets with the current topographic base map at the former junction between the Adige River and the Noce River.

On the two maps, easily recognizable landmarks have been identified, such as churches, buildings and bell towers that have remained in unchanged positions over time.

The use of a second-order polynomial affine transformation combined with a nearest neighbour resampling allowed to limit the distortions of the georeferenced map within values that take into account both the corresponding graphical error at about 4 meters, the original accuracy of the historical map and the loss of information deriving from the physical degradation of the paper, different reproduction procedures, including its digitalization. The high number of points identified on both maps for georeferencing (up to 47 GCPs per sheet) and the number of points used for control, typically 20, allowed to reach an accuracy level of 10 to 15 meters in terms of RMSE, depending on the number of points used as GCPs for the projection. This error is not very far from that obtained by Dai Prà and Mastronunzio (2014) which have geo-referenced some sheets of the 1: 3,456 scale Claricini map, also using the Habsburg cadastral map sheets (1853-61) as a reference (Buffoni et al., 2003), and obtained an RMSE of 5 to 6 meters using 24 GCP and the CTP itself as a reference map. Another result of the georeferencing process was the observation that the actual scale of the "Claricini Tridentina" map is close to 1:22,000, instead of the nominal value of 1:20,736. The reason could be related to the process of engraving the original lithography, or the effect of paper deformation.

Geomorphology of the Adige River

The river morphology is defined by Lane in 1955 as the science that studies the form produced by the action of a watercourse. Studying the morphology of a watercourse is fundamental for an integrated land planning, river training and environmental protection. Historical maps, such as the "Claricini Tridentina", allow to have a past vision of the territory occupied by a water course, in a condition close to its natural state.

The morphological study carried out here analysed the 146.2 km-long reach of the Adige valley from Merano to Borghetto in two different periods: in 1847, through the georeferenced historical map, and in the present period through the CTPs, in vector format, of the Autonomous Provinces of Trento and of Bolzano. These two analyses were also compared with the morphology of the Adige at the beginning of the 1800s, studied by Scorpio et al. (2018) for a shorter reach 115 km-long. To assign a specific morphological type to a river section, it is necessary to calculate three planimetric indexes: the sinuosity index, the anabranching index and the braiding index. The first index is defined as the length of the planimetric layout of the thalweg divided by the length of the valley. The anabranching index and the braiding index are defined as both the sum of the number of active channels measured along cross sections in a reach divided by the number of equidistant sections considered; the difference between the two indices is the geomorphological unit that separates the active channels. The braiding index considers the river bars, which are stable depositional forms having the same grain size as the bottom emerged for most of the year, while the anabranching index considers the river 'green' islands, which are bars having, instead, stable riparian vegetation. The digitization and calculation of these indices was performed in a GIS environment and the average widths of the individual morphological types and the length of the planimetric layout in the two different periods were compared. The hydrometric condition was verified to be similar, based on channel width at some reference cross-sections.

Table 1. Length, *L*, and width, *B*, of the Adige river at 1847 and in the current period.

	Claricini	Current	Δ (%)
L (km)	146.2	136.6	-7
B_{min} (m)	30.4	28.8	-6
$B_{average}$ (m)	103.9	67.2	-35
B_{max} (m)	216.0	93.9	-57

Table 1 shows the relative results of the decrease in length of the riverbed, due to the adjustments, and the decrease in width of the riverbed, due to the incision induced by anthropogenic interventions in the riverbed. The different morphological models were highlighted in the two planimetric tracings, comparing them with the detailed study by Scorpio et al. (2018) for the river reach from Merano to Calliano, 31.2 km upstream Borghetto. Figure 2 shows the three planimetric layouts; the historical maps show the typical development of the fluvial morphology, that is in the areas further upstream the water course presents models with multiple channels, with braided and anabranching river morphology, while downstream the dominant model becomes the meandering or sinuous one.

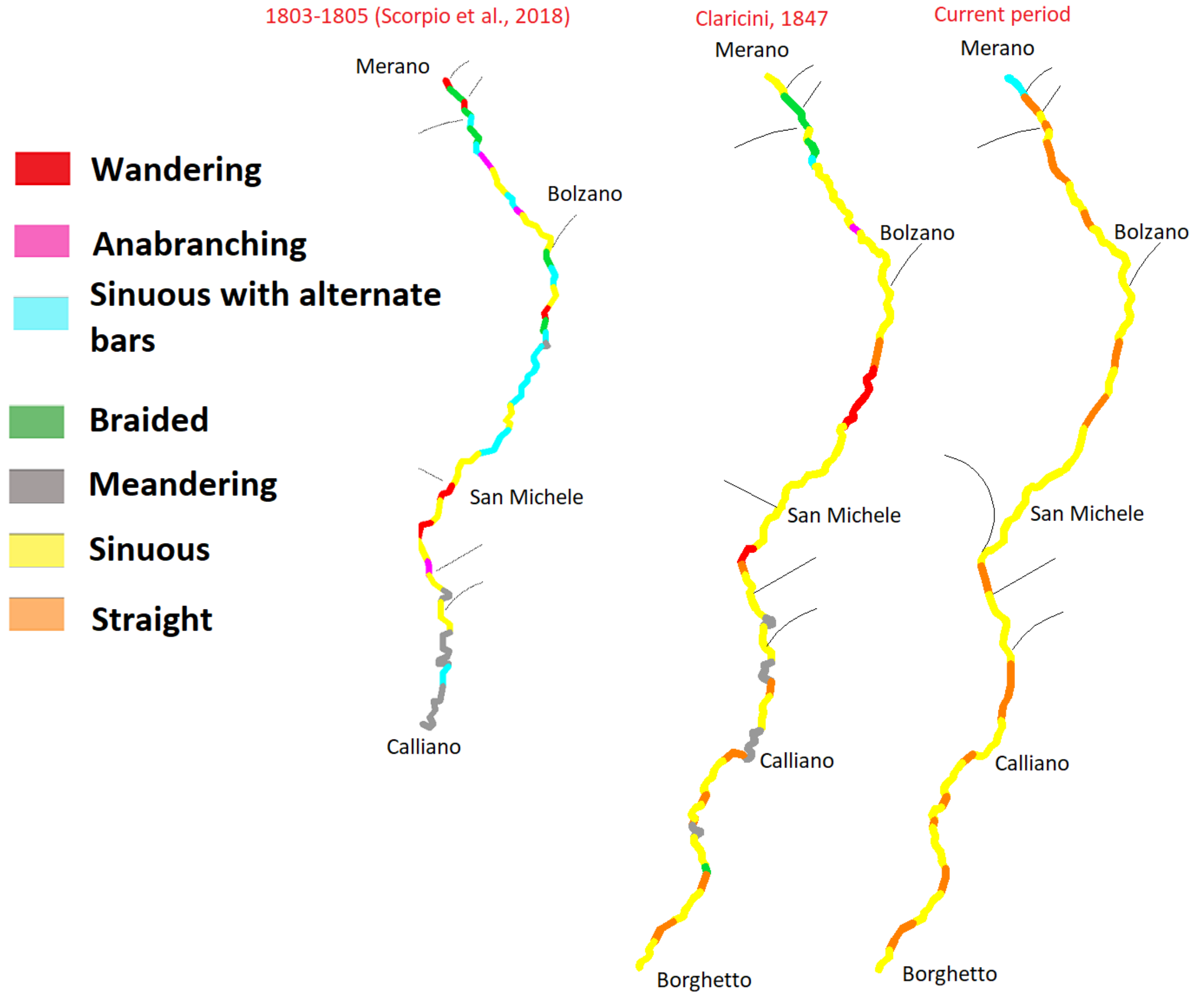

Figure 2. Adige river morphology in different historical periods.

The effect of the river rectification in the reach between Bolzano and San Michele which started after the year 1815 impacted on the river morphology already observed in 1847.

In addition to these results it is also possible to compare the old situation with the current morphological analysis, since it is possible to recognise that today after the channelization works completed at the end of the XIX century the only surviving river types are the sinuous and the straight ones with the exception of a short sinuous reach with alternate bars surviving downstream Merano. A dramatic loss of variability of river morphology in the last two centuries can be observed and this has an impact both on the landscape and on river hydraulics. Table 2 and 3 show the percentage lengths of the bed of the various morphological models in the two different periods, in addition to the relative widths of the river bed. The river width in sinuous and straight river reaches shrunk significantly by a factor 1/3 and most morphologies disappeared definitely.

Table 2. Length and width of the Adige river in 1847.

L stretches (km)		L%	B_{min} (m)	$B_{average}$ (m)	B_{max} (m)
Sinuous	89.7	61.3	30.4	94.8	159.6
Braided	9.7	6.6	133.7	163.0	216.0
Sinuous with alternate bars	1.3	0.9	143.0	143.0	143.0
Anabranching	1.3	0.9	83.6	83.6	83.6
Straight	17.9	12.3	64.0	94.1	135.3
Wandering	11.7	8.0	91.4	100.2	127.8
Meandering	14.6	10.0	82.8	100.4	117.1

Table 3. Length and width of the Adige river today.

L stretches (km)		L%	B_{min} (m)	$B_{average}$ (m)	B_{max} (m)
Sinuous	90.2	66.0	39.4	68.8	93.9
Braided	0	0	0	0	0
Sinuous with alternate bars	3.4	2.5	28.8	28.8	28.8
Anabranching	0	0	0	0	0
Straight	43.1	31.5	34.5	64.4	93.5
Wandering	0	0	0	0	0
Meandering	0	0	0	0	0

Hydraulic modelling

The consequences of the changes in the levee system configuration on the Adige River's flood dynamic were investigated by simulating the propagation of some observed events in different river bed conditions. Hydrodynamic simulations were conducted by using Hec-Ras modelling software (US Army Corps of Engineers, 2016), with reference to the river reach between the sections of Bronzolo, short downstream Bolzano, and San Michele all'Adige. This river reach is 26 km long and is included between the upstream junction of the Isarco River (left-bank tributary) and the downstream junction of the Noce River (right-bank tributary).

The current levee system configuration is the result of progressive levee crest raisings, aimed at mitigating the risk of levee failures because of overtopping. According to Ranzi et al. (2015), who documented the evolution of the Adige River's flood defence system after the description by Weber von Ebenhof (1892), levee crest elevations were increased of about 2 m since 1868. As it can be seen in Figure 3, the numbers of levee failures recorded between Merano and San Michele all'Adige due to various flood events occurred from 1868 to 2012, substantially decreased as the levee crest raisings were brought to completion.

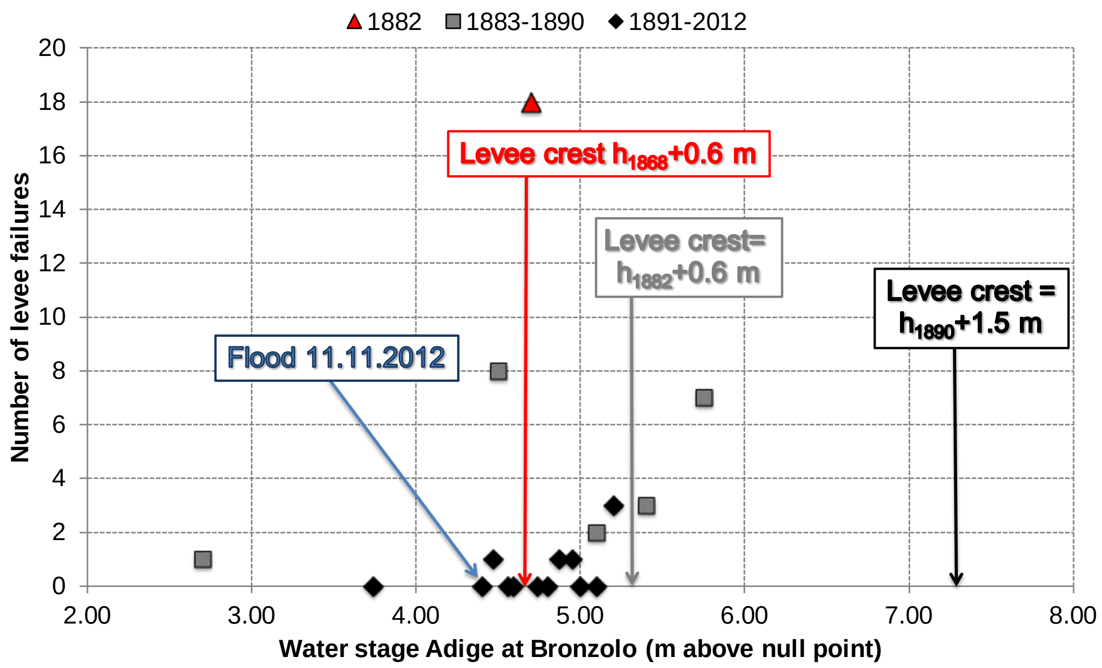

Figure 3. Numbers of levee failures recorded from 1882 and 2012 between Merano and San Michele all'Adige, evidencing levee crest raisings (modified from Ranzi et al., 2015).

Thus, two additional levee configuration scenarios were developed with respect to the current one, which can accurately be delineated due to a number of surveyed river sections made available by the Hydrographic District Authority. The 1868-1882 scenario and the 1882-1890 scenario were obtained by considering the current levee crest elevations, 1.95 m and 1.54 m higher than those raised after the 1868 and 1882 floods, respectively. The oldest scenario accounts for an almost natural condition of the river course.

With reference to the Bronzolo section, where a historical river gauge station exists, three major floods occurred in the Adige River were modelled. The estimates of their main characteristics are listed in Table 4. The event occurred in 1882 has a historical importance, since it is one of the first floods ever observed at the Bronzolo river gauge (Weber von Ebenhof, 1892). Its hydrograph was approximated by using daily hydrometric observations, linearly interpolated. The knowledge of the event occurred in 1926 was instead more complete, since most of the flow discharges were assessed by using sub-daily water stage observations and the normal rating curve. Finally, the event occurred in 1966 was recorded by the hydrographic service. As it can be noticed, the events occurred in 1926 and in 1966 significantly differ in terms of flood volumes, even though they show quite similar peak discharges.

Table 4. Summary of flood event characteristics in Bronzolo river section.

Date	Peak discharge (m^3/s)	Peak return period (yrs)	Flood volume (10^6 m^3)
17th September 1882	1251	15	510
1st November 1926	1453	40	470
4th November 1966	1396	30	190

Return periods in Table 4 were estimated with regard to the sample of maximum annual peak discharges observed at Bronzolo and reported in Villi and Bacchi (2001). The corresponding hydrographs were implemented in the flood propagation modelling as upstream boundary conditions, to integrate the differential equations governing the unsteady flow of shallow waters in open channels (Chow, 1988). Figure 4 shows the result obtained for the flood occurred in 1926, the most severe case herein taken into consideration. As it can be seen, a consistent attenuation of the flood peak discharge would have been occurred under the former levee systems configurations.

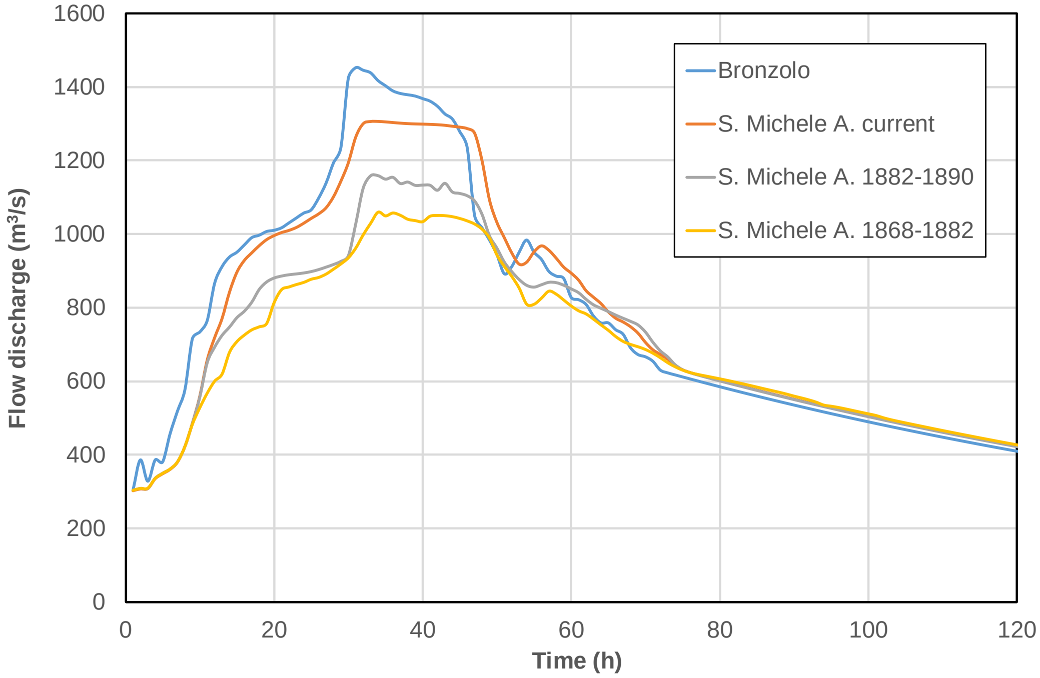

Figure 4. Routing along the Adige River between Bronzolo and San Michele all'Adige of the flood occurred in 1926, under different river levees conditions.

A summary of the results is provided by Table 5, where the ratios between the peak discharges obtained in San Michele all'Adige river section in the former configuration and those obtained in the current one are reported. It is evident that the levee crest raising determined an appreciable increase in the flood peak discharges downstream as those assessed in the almost natural conditions antecedent to the year 1882 are about 20% less that those expected in the current configuration. The ability of controlling the flood events, achieved by using conventional structural practices, actually determines a dramatic reduction of the overflow volumes, which can be advocated as the major cause for the loss of the peak discharge attenuation capacity.

Table 5. Ratio between the peak discharges in San Michele all'Adige river section in the former levee system configurations with respect to those in the current one (%).

Levee system scenario	Flood event		
	1882	1926	1966
1868-1882	86.8	95.7	87.6
1882-1890	80.5	81.1	79.5

Tracing dry stone walls, UNESCO Intangible Cultural Heritage

Another objective of the geo-referencing of Claricini's map is to promote the knowledge and conservation of the remarkable cultural, landscape and land conservation heritage represented by dry stone walls and terraced slopes systems in the Adige valley. As stated before, in January 2019 UNESCO declared the art of constructing dry stone walls an Intangible Cultural Heritage. In effect, on the geo-referenced map of Claricini, in addition to the main communication route "Post Strasse", now transformed into a high-speed road (in orange in Figure 5), there are also a lot of secondary roads serving urban areas and providing access to agricultural crops, mainly vineyards. Many of these roads are still marked by the symbol of dry stone walls (in red in Figure 2) in the actual Province Technical Map, together with terraces in agricultural crops, marked in yellow.

Figure 5. Dry stone walls of terraces (yellow) and along secondary roads (red) next to Ala di Trento.

Therefore, the identification of old minor roads on the Claricini map can help in assigning to the year 1847 the value of a '*terminus ante quem'* for dating dry stone walls.

The study of the geo-referenced map can support the recovery of this historical heritage, as well as educating people about the landscapes of dry stones, spreading knowledge and sensitivity about their characteristics, functions and potential. A study of this type also promotes the cultural identity and the awareness of those who work in this territory about the importance of safeguarding dry artefacts with recovery activities, reconstruction, conservation and restoration practices.

Conclusions

The operation of georeferencing the 14 sheets of the small scale Claricini map of the Adige river confirmed the quality of the topographic survey and map printing, as a mean Root Mean Square Error between 10 and 15 m on some tens of Ground Control Points and 20 verification points per sheet resulted, on average. The georeferenced maps allowed the comparison of the river geomorphology in 1847 and actual conditions, which marked the disappearance of anabranching, braided and meandering rivers morphologies. Average channel width in similar hydrometric conditions shrunk by a factor of 1/3.

Raising of levees as an effect of the river channelization impacted on a 20% attenuation capacity of flood peaks in the original almost natural conditions compared to today's conditions for three major floods simulated.

By digitizing on the Claricini map minor country roads it is possible to highlight the year 1847 as a candidate '*terminus ante quem*' for the construction of some dry stone walls which are present especially in the lower Adige valley and are worth to be protected and conserved as a landscape heritage especially now that UNESCO declared the art of constructing dry stone wall an Intangible Cultural Heritage.

Acknowledgments

The authors thank Fondazione Cariplo for funding this research through the FLORIMAP grant.

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* Summary
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