The 'Deluge' of 25 October 1822 in Genoa, Italy

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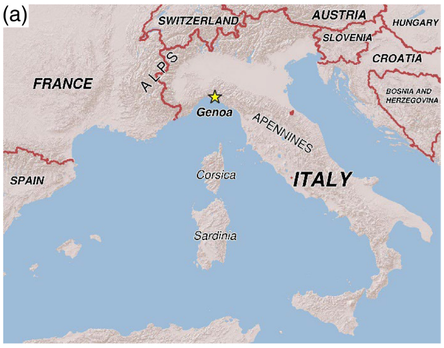
Floods in Genoa

Located at the northern apex of the western Mediterranean Sea (Figure 1a), the city of Genoa is prone to catastrophic flooding triggered by heavy rainfall. There is historical documentation of such events since the Middle Ages (Faccini *et al*., 2016). Amongst the areas of the city affected by floods, the lower Bisagno Valley in the eastern part of the city is most notorious for being affected. Intense rainfall phenomena are linked to these events, which often represent meteorological records: the deluges of 7–8 October 1970 and the 4 November 2011 recorded 948mm/24h and 718mm/12h (1970) and 181mm/h, 337mm/3h and 472mm/6h (2011), respectively: these are exceptional values, especially when considering that the average annual rainfall cumulated over Genoa is only an approximate 1250mm (Genoa University station, measurements started in 1833). In recent years, climate change has caused a change in the rainfall regime which is more intense and concentrated, alternating with long periods of drought, as well as an increase in average annual air temperature (Acquaotta *et al*., 2018, 2019).

(a)



(b)

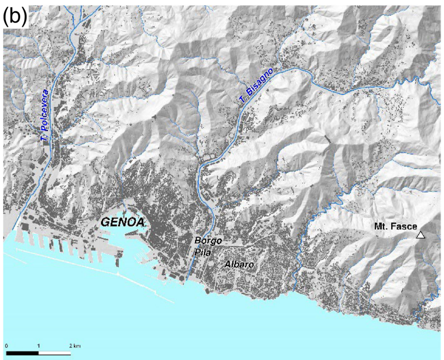


Figure 1. Geographical maps of studied area: (a) Genoa city in the West Mediterranean; (b) Genoa municipality between Polcevera stream and Mt. Fasce.

The reason for the occurrence of heavy rainfall and the resulting surface effects is partly related to meteorological aspects, in particular a typical low-pressure area that forms over the Gulf of Genoa, and partly to the physical and geographical layout of the nearby river catchments. The region is characterised by a mountain ridge with relief of significant height (over 1000m asl) at a short distance from the coastline, interrupted by relatively low mountain passes (400–500m asl) that occasionally convey colder air from the Po Valley. In the autumn period, a depression tends to form in northern Gulf of Genoa (known as the 'Genoa Low') as a result of moist and cold air flowing from the North Atlantic into the Mediterranean through the Rhone Valley between the Alps and the Massifs Central. On entering the northwest Mediterranean, the cold air impacts on the Corsican and Sardinian mountains (Figure 1a), which deflect the air current towards the north, triggering the response of humid winds from the southwest that rise up towards the Ligurian Gulf, where they impact on the coastal mountain ridge. A complex interaction is established between the orographic context and the contrast between the cold, humid air and the warmer water of the Ligurian Sea; this process results in the formation of an area of low pressure right over the Ligurian coast.

The effects on the ground are emphasised by the physical and geographical layout of the river catchments and geomorphological processes, both natural and anthropic: the steep gradient of the slopes, and a dense built-up surface, often with significant modifications to the hydrographic network, which make the propagation of floods very rapid and unpredictable (Faccini *et al*., 2015, 2018; Piana *et al*., 2019).

This research presents the flood event in the lower Bisagno Valley on 25 October 1822, when more than 12h of heavy rain caused a catastrophic inundation, with very serious effects on the ground, damage to buildings, infrastructure and loss of life (Rosso, 2014). The event had a great emotional impact on the local society, as it was described by local painters, foreign travellers and scientists, who were struck by the phenomenon. The estimated rainfall, and consequently the flow rate of the watercourse, was not taken into account more than a century later during the design stages of building culverts, leading to a significant increase in flood risk, particularly from the 1940s onwards.

Scientific data from 1822

Data of the flood event of 1822 were recorded by Professor Antonio Pagano from the University of Genoa, who measured 30in. of rain (812mm) in Marassi district in the lower Bisagno Valley; this value corresponds to a return period of more than 500 years (Autorità di Bacino Distrettuale dell'Appennino Settentrionale, 2022).

The rain began in the night between the 24th and the 25th and lasted *c*. 15h, becoming intense around 10:00 on the 25th when most of the walled gardens of the valley had already been inundated (Faccini *et al*., 2016). The peak of the flood on the Bisagno took place around 11:30, when most of the worst surface effects had already occurred. Pagano's exceptional data were shared amongst the international community and the flood of Genoa still represents one of the most significant rainfall events ever recorded in nineteenth-century Europe. The *Annales de Chimie et Physique* by Arago and Gay Lussac confirmed the accuracy of the data, defining Pagano as an '*observateur exact*', referring to a correspondence the Professor had with the Universal Library of Geneva about his methodology (Gay Lussac and Arago, 1824, pp 406–407):

> *'This never before heard of (incredible) data raised some doubts amongst meteorologists and some measurement mistake is suspected. But Mr. Pagano, exact observer, wrote a letter to the editors of the Biblioteque Universel which puts the fact beyond dispute. He reports that two empty cylindric wooden buckets, respectively 24 and 26 inches high […] were completely filled before the flood of 25th October had ended.*

After all, this meteora *sort of storm (a large quantity of rain) did not affect a large area'.*[1]

Other contemporary scientists were more doubtful about the accuracy of this measurement. In the *Supplementary Report on Meteorology* in the *Report of the Tenth Meeting of the British Association for the Advancement of Science* (1841) James Forbes, Professor of Natural Philosophy at the University of Edinburgh considered the measurement '*by no means the less satisfactory because it was obtained by the most inartificial of rain-gauges*' (Forbes, 1841, p 113). However, he added that the data are validated by a '*similar fact recorded in the South of France by an experienced observer*', M. Tardy de la Brossy of Joyeuse (1841, p 114). Many other scientific publications of the following years remembered the flood of Genoa including *Introduction to Meteorology* by David Thompson (Thompson, 1849) and the *Minutes of Proceedings of the Institute of Civil Engineering* by Manby and Forrest (1859). Although some uncertainty regarding the real amount of rainfall remains, the surface effects of the 1822 flood described in the following paragraphs make Pagano's data realistic and generally comparable with the most recent flood events that affected the Bisagno Valley.

Overall, damage losses and other damages included two collapsed bridges, disruption to shops, farms, factories and the public aqueduct. The estimated damage was around half a million of Savoy liras (Faccini *et al*., 2016).

Chronicle of the flood event from local newspapers and written reports

Contemporary accounts state the flood started during the night between Thursday 24th and Friday 25th October 1822. The area affected by the event was limited to the catchments of the Bisagno and Sturla Valleys between the city of Genoa and Monte Fasce (Gazzetta di Genova, 30 October 1822, p 334) (Figure 1b). The flood was particularly devastating in the Sturla Valley, and in Albaro and Borgo Pila on the Bisagno. Here, the river destroyed walls and allotments and inundated the lower floors of hundreds of buildings, including the church of Santa Zita (Gazzetta di Genova, 26 October 1822, pp 339–340). Two bridges on the Bisagno, Sant'Agata and Porta Pila, collapsed, and communications with the Eastern Riviera and Tuscany were interrupted for several days as the Bisagno was so furious that no one could cross it by boat and the crossing was obstructed by large numbers of branches and fallen trees. A provisional bridge was then built in the following days to allow eastbound travellers to cross the river. Contemporary journals report crowds gathering along the bank of the torrent and according to Gazzetta di Genova:

> *'In most shops of Borgo Pila water was ten palms*[2] *high and in the lower part […] 11 palms high. Neither was this was the greatest height; as along the road to Albaro, near the house called Steria, where several streams flow, the water reached twelve and a half palms. Damages by this fatal accident are enormous. The Borgo of Pila is formed by shops and warehouses where rich storages of oil, wine, flours, cloths and all other goods are kept. Such was the sudden impetuousness of the waters that people had little time to move some goods to the higher floors or to save people. At ten in the morning there was no apparent sign of danger but in an hour's time all the evil was done. Many of the above shops will have a damage of two-three thousand liras: a shop of ropes will have losses around eight-nine thousand liras, etc. Loss of livestock has been quite considerable; the worst case having been the death of c. seventy animals in a stable at Sant'Agata'* (Gazzetta di Genova, 26 October 1822, pp 339–340).[3]

The vivid description of the *Gazzetta di Genova* is the most complete known report of that event, but references to it survive in written accounts that provide evidence of how not only the final stretch of the river valley, but the entire Bisagno Valley was affected. In his *Viaggio nella Liguria Marittima* the Turin-born journalist and travel writer Davide Bertolotti described, with a mixture of scientific detail and personal emphasis, the floods of the Bisagno with particular reference to the event of 1822[4]:

> *'Occasionally the Bisagno increases excessively. It then devastates every obstacle including garden walls, it destroys the lateral roads and the arches of old bridges. Occasionally it happens that while the river bed is dry, with clothes that women lay to dry or to whiten, screams of terror are heard, and warnings from the distance are promptly repeated and echoed from the upper, sinuous valley, which make the peasants on the hills worried for his wife and child who went down to the valley floor. Those screams announce that water is coming down. A sudden development of clouds over the mountains generates these floods which precipitously fall and inundate. The bareness of slopes does not pose an obstacle to water, which falls violently, neither plants nor vegetation can stop it. Thousands of streams simultaneously flood from above and the uncontrollable river, suddenly raised, floods and doubles its fury at every step. And really, the water's strength that unexpectedly falls down is such that the man who is in the middle of the pebbly river bed and sees the turbid and disastrous stream coming down, can not always escape. A frightful flood of the Bisagno, but not one of these sudden ones, happened in 1822. This unfortunate event is still remembered by inhabitants and its damage is still evident. The flooding river swept away the nice embankment built in the French time to protect the road [along the Bisagno]'* (Bertolotti, 1834, pp 5–6 and 9–10).

Archival accounts confirm that a stretch of the new road built under Napoleon was destroyed in Staglieno 'during the famous flood of San Crispino of 1823 [1822]' as the new road did not have an appropriate drainage system.[5] The flood was known as 'flood of San Crispino' from the saint of that day (25 October). Its intensity was such that in 1878 Podestà refers that '*there is no old person who does not remember with horror and describes without emotion the fall of water of that day*' (1878, p 34).

At the time, the flood event was depicted in two different views by the Genoese topographical artist Luigi Garibbo (1782–1869) who later became very popular for his extremely realistic paintings made 'en plein air' (Papone and Serra, 2011).

The first view is an aquatint that depicts the furious waters of the Bisagno and the collapsed Pila bridge in background with the church of Santa Zita on the left during the flood event (Figure 2). Children, women and men of all social classes are gathering along the right bank of the river where a body was just recovered from the water. On the right background of the image the walls of Genoa and the ancient gate of Porta Pila, which also gave its name to the bridge depicted. A second view shows the Bisagno from the same viewpoint as the flood is beginning to subside. Just like the previous view, some boats are crossing the muddy waters of the Bisagno but a provisional wooden bridge is already operational and communications between Genova and the Eastern Riviera are restored (Figure 6.1). Evidence of the damage of the 1822 flood is also detectable from contemporary cartography, particularly

[1]Original text in French, translated by the authors.

[2]Genoese Palm, unit of measurement corresponding to 0.248083m.

[3]Original text in Italian, translated by the authors.

[4]Original text in Italian, translated by the authors.

[5]Archivio di Stato di Genova, Prefettura Sarda 189, *Incanalamento delle acque di due fossati nel letto del Fiume Bisagno per mezzo di acquedotti da costruirsi sotto la nuova strada* (1835).

Figure 2. View of the Pila bridge over the Bisagno river near the walls of Genoa shortly after it was ruined by the great flood of October 26th, 1822, by Luigi Garibbo ('Veduta del ponte della Pila sul Bisagno presso alle mura di Genova poco dopo il suo diroccamento per la gran piena del 26 Ottobre del 1822', Centro DocSAI, Collezione Topografica del Comune di Genova).

Figure 3. Stretch of the Bisagno Valley showing the new iron bridge and the erased collapsed bridge of Santa Zita, Archivio Storico Istituto Geografico Militare (Riviera di Levante alla quarta della scala di Savoia ossia di 1:9450 eseguita negli anni 1816, 1822, 23, 24, 25, 1826 e 1827, foglio 78).

from a topographical map produced by the Sardinian Kingdom where a detail of this stretch of the valley shows that the old bridge destroyed in 1822 was erased by the cartographer (Figure 3). After its collapse, Santa Zita bridge was replaced by a new iron bridge designed by the engineer Luigi Barbavara, which opened in 1835 (Podestà, 1878).

While the new bridge was being built, a provisional wooden bridge allowed passage between the two ends of the broken Santa Zita bridge. This is shown in a watercolour by the Genoese artist Pasquale Domenico Cambiaso (Figure 4). The view direction is the opposite of the two depictions by Garibbo, located along the right-hand side of the Bisagno. Cambiaso's viewpoint is much closer to the bridge, showing the details of its structure and its position in relation to the village of Santa Zita. Some young women on the right are washing their clothes along the river, a very common sight in pre-industrial Liguria (Piana *et al*., 2018).

Written accounts by foreign visitors in Genoa

In addition to being reported by local newspapers and commentators, the flood event was widely described by foreign visitors who were residing in Genoa at the time. The city was historically included in the Grand Tour (Black, 2003) and after the Napoleonic wars it was increasingly visited by foreign travellers (Piana *et al*., 2021) including illustrious personalities such as Lord Gordon Byron (1788–1824) and Mary Shelley (1797–1851) who were residing in the city in October 1822 and directly witnessed and reported on the event.

At the time Lord Byron was living in Albaro, an eastern suburb of Genoa which dominates the Bisagno Valley from a hill. In a letter to his stepsister Augusta Leigh, Lord Byron described the event as follows:

> *'We had a deluge here – which has carried away half the country between this and Genoa – (about two miles or less distant) but being on a hill we were only nearly knocked down by the lighting and battered by columns of rain – and our lower floor afloat - with the comfortable view of the all landscape under water – and people screaming out of their garret windows – two bridges swept down – […]. The whole came on so suddenly that there was no time to prepare - think only at the top of the hill – of the road being an impassable cascade – and a child being drowned a few yards from it's own door (as we heard say) in a place where water is in general a rare commodity'* (Byron, 1980, Letter 10, pp 28–20).

In *Rambles in Germany and Italy* (1844), Mary Shelley described with vivid detail and scientific accurateness the thunderstorms that are often seen in continental Europe, a type of meteorological phenomenon which is very rare in Britain. She refers to a 'perilous journey' over the Splugen Pass in 1834 by Hayward under a violent Alpine thunderstorm, comparing it to the flood of October 1822 in Genoa:

> *'I once witnessed a phenomenon of this sort at Genoa. The Italians called it a* Meteora. *A cloud, surcharged with electricity and water, burst above our heads in one torrent of what was rather a cataract than rain. It lasted about twenty minutes, and sufficed to carry away all the bridges over the Bisanzio, flowing between Genoa and Albaro, and to lay flat all the walls which in that hilly country support the soil – so the landscape was opened and greatly improved. Cottages, cattle and even persons were carried away'* (Shelley, 1844, p 58, note).

Other nineteenth-century travellers underlined the dangerousness of the Bisagno, providing evidence of the frequency of flood events: Bunnett (1844, p 29) observed that 'the Bisagno which, though dry during the summer heats, becomes a furious and overwhelming stream in the rainy season'.

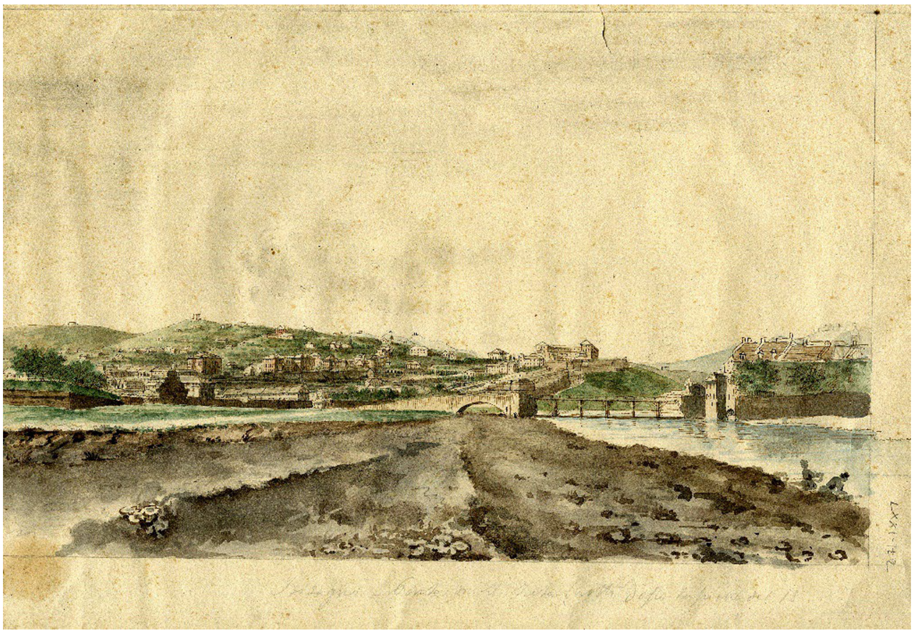


Figure 4. A watercolour by the Genoese artist Pasquale Domenico Cambiaso, showing the provisional wooden bridge (Pasquale Domenico Cambiaso, Bisagno, ponte di S. Zita rotto dopo la piena del 1822, Centro DocSAI, Collezione Topografica del Comune di Genova).

Figure 5. Historical map comparison (from Italian Military Geographical Institute maps, 1:25 000 scale, ed. 1878 and 1939) and corresponding stream cross-section at the mouth. (Modified from Inglese et al., 1909.)

Underestimation and consequences

A more detailed analysis and evaluation of both the meteo-hydrological aspects and ground effects of the flood of 1822, gathered from both scientific literature and historical-geographical sources, would have probably avoided, or at least reduced, flood damage that occurred in the following centuries, especially after the construction of the culvert containing river's final section in the 1930s. Underestimating the rainfall and consequent stream flow associated with the flood of 1822 was a serious mistake which was highlighted during the evolution of the same area over the following century. The rainfall events of the nineteenth century (in addition to 1822, we highlight those of 25 August 1842, 17 October 1872 and 8 October 1892) recorded major surface effects in the lower valley when, before urbanisation, the Bisagno could still expand along wide areas of the corresponding floodplain.

This natural floodplain smoothed out the peak flow in the terminal section, which, as shown by historical maps, was characterized by historical settlements, gardens and a dense network of water channels for agriculture. With the gradual and often irrational urbanisation of the slopes, which also involved floodplain sealing, the main and minor river networks were narrowed, channelized and locally culverted, including the terminal stretch of the Bisagno, as shown in Figure 5.

At the beginning of the twentieth century, a team of hydraulic engineers was commissioned to design the culvert of the terminal section of the Bisagno. The hydro-meteorological data noted by Pagano, the surface effects described by the various iconographic and written sources were not considered significant, and a rectangular area suitable for disposing of an expected flood of 500m^{3}s^{-1} was designed (Figure 5; Inglese *et al*., 1909). Channelisation work on the first section began in 1928 and was completed in 1933; in 1934 the second overlay project was approved up to the mouth, which was carried out in 1936. The image comparison of Figure 6 shows the view of Garibbo and two present-day images from the same viewpoint and from an elevated position, providing evidence of the significant landscape changes the area went through in the last century.

Overall, the hydraulic section was designed for a maximum flow rate of 600m^{3}s^{-1}. Meteo-hydrological data for the 1822 event determine a stream flow rate in the terminal section of the Bisagno around 1200–1300m^{3}s^{-1}, more than double of the hydraulic design of the current culvert; this miscalculation is therefore

RMetS Royal Meteorological Society

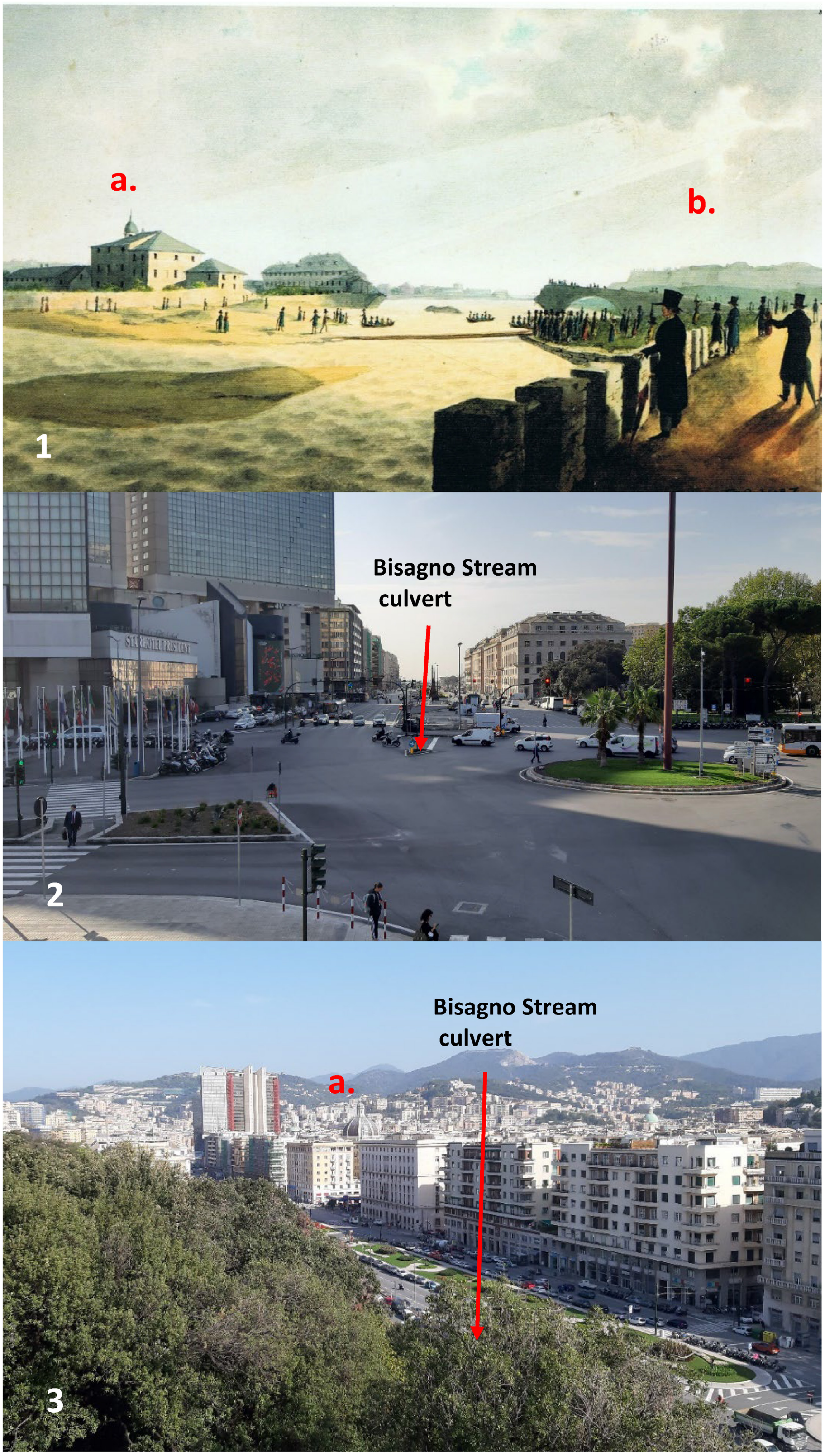


Figure 6. Landscape changes in the terminal stretch of the Bisagno between 1822 and today. (1) Luigi Garibbo, Il Ponte Pila rotto dal Bisagno, Centro DocSAI, Collezione Topografica del Comune di Genova (a. Church of Santa Zita; b. Santa Chiara walls); (2) current view from Garibbo's viewpoint; (3) current view from (b).

associated with most of the floods that have occurred since 1945 along the final stretch of the Bisagno (Rosso, 2014).

The Bisagno stream floods have been classified into three categories, based on the intensity of ground effects (e.g. casualties and damage). This subjective classification allows an easy comprehension of the flood events distribution over the past two hundred years and the disastrous effect due to the incorrect design of the culvert (Figure 7).

Amongst the most catastrophic events were those of 29 October 1945 (flash flood), 19 September 1953 (flash flood) and especially 7/8 October 1970 (regular flood), while in the past 30 years, the events of 27 September 1992, 4 November 2011, and the most recent one of 9 October 2014 (flash floods), can be recalled within living memory. Except for the 1953 flood, all the events described from 1945 to present day have involved loss of life.

The disastrous flood of 1970, which followed those of Florence and Venice (1966) by a few years, led to a fervent national debate about solutions to reduce the serious situation of the Bisagno stream. Three possible strategies were identified: (a) construction of a diversion of the watercourse through a tunnel; (b) construction of a partial spillway of the flood flows of the watercourse, through a tunnel carrying water to the sea; (c) demolition of the terminal culvert, restoring the original riverbed's width.

Certainly, solution (c) would have been the most compatible and acceptable one from a natural and landscape point of view; however, for urban planning and viability reasons, preliminary and final designs for the Bisagno Stream spillway have been carried out since 1986. Today, the Bisagno stream spillway construction site is active and a tunnel capable of diverting a maximum flow of about 400m^{3}s^{-1} away from the natural riverbed is being built.[6]

Conclusions

Liguria and Genoa are characterized by particular hydro-meteorological and geophysical conditions that determine short but intense rainfall events particularly in autumn (Acquaotta *et al*., 2018, 2019). The related ground effects, due to the geomorphological and environmental setting of the Tyrrhenian catchments, are represented by flash floods (usually less than 24h in duration) where the offset between peak rainfall and peak discharge is extremely short, even less than 1h. Historical sources report severe flooding events since very ancient times, but in the last 200 years episodes with very severe ground effects have a rainfall history ranging from 20 to 100 years in return time (e.g. 1970, 1992 and 2014 events) and represent one of the most serious threats to public safety (Paliaga *et al*., 2020; Autorità di Bacino Distrettuale dell'Appennino Settentrionale, 2022). Only in the third millennium have there been several hydro-geological processes that have resulted in loss of life, the last one being on 9 October 2019.

Since World War II, ground effects resulting from heavy rainfall appear to have grown, partly due to urban sprawl and general anthropogenic impact on the natural catchment, including channelisation and coverage of streams, and partly due to climate change, above all change in rainfall regime (Acquaotta

[6]https://scolmatorebisagno.it

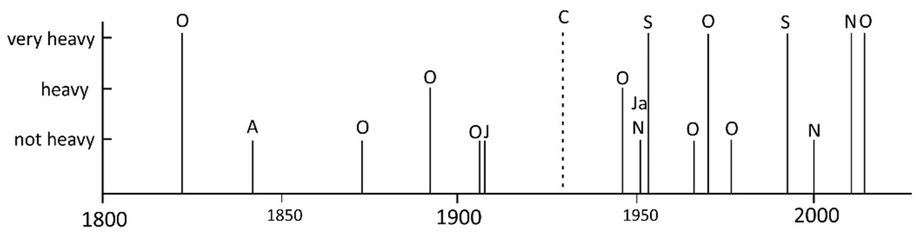


Figure 7. Temporal changes in floods since 1800, Ja = January; J = July; A = August; S = September; O = October; N = November. C = culvert construction. NB. 1951 had a January and November flood.

et al., 2018, 2019). Catastrophic events in living memory include the event of 7/8 October 1970, which resulted in Mediterranean records of rain intensity over 3, 12 and 24h, the latter which still remains unsurpassed.

This research, however, has revealed that even the flood of 25 October 1822, reconstructed with written accounts, weather reports and iconographical sources, was comparable to those of the past 80 years in terms of rainfall intensity and disastrous ground effects despite the very limited urbanisation of the floodplain in the early nineteenth century. This case study is considered particularly interesting and demonstrates the importance of using historical-geographical sources, written and iconographic material for the study of historical natural hazard events (Colin 2014; Veale and Endfield, 2016), and demonstrates the fruitful multidisciplinary approach involving natural and social scientific disciplines for the purpose of understanding past hydro-geological events also for the direction of associated risk reduction and to increase societal resilience.

Acknowledgements

The authors would like to thank the co-Editor-in-chief Edward Graham and the two anonymous reviewers for their careful reading of the manuscript and their many insightful comments and suggestions. They would also like to thank the staff of Centro di Documentazione per la Storia, l'Arte e l'Immagine di Genova (DocSAI). Open Access Funding provided by Universita degli Studi di Genova within the CRUI-CARE Agreement.

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doi: 10.1002/wea.4388