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The signs of the 1978 flood in the Vigezzo Valley (Northern Italy): a Citizen science project in the Sesia Val Grande UNESCO Global Geopark

Abstract: Bollati I.M., Guerra C., Minacci L., *The signs of the 1978 flood in the Vigezzo Valley (Northern Italy): a Citizen science project in the Sesia Val Grande UNESCO Global Geopark.* (IT ISSN 0391-9838, 2023). On 7th-8th August 1978, a serious flood hit the Vigezzo valley, in the northeastern part of the Sesia Val Grande UNESCO Global Geopark (Northern Italy). The flood, strictly linked to the bedrock features, was triggered by heavy rains and made even worse by unsuitable urban sprawl. It left obvious scars in the landscape, which are now gradually being lost. The local population, as well as tourists, have a deep memory of the event, especially old people. Herein, we describe the Citizen Science Project, named *The signs of the 1978 flood in the Vigezzo Valley: the population tells.* Data collection started in 2021, through citizen collaboration (residents and tourists) and is still ongoing. With the support and patronage of many local entities (e.g. Municipalities), particularly the Regional Ecomuseum 'Of the Soapstone and of the Stone-cutters' ('*Ed Leuzerie e di Scherpelit*' in local dialect), in the Malesco Municipality, an electronic form/paper survey was distributed to collect information and pictures on the flood event, and to select the most meaningful sites in the valley, relating to the event. Thirty four sites were suggested by citizens and will be considered considered to create a community map and a trail of the flood event, to preserve and transmit this heritage to future generations. The Citizen Science Project is also discussed, as a contributor to different Sustainable Development Goals (mainly SDGs 4-9-11-13-17) of Agenda 2030 of the United Nations, in the framework of the Sesia Val Grande UNESCO Global Geopark.

Key words: Flood events, Sesia Val Grande UNESCO Global Geopark, Citizen Science, Community maps, United Nation Sustainable Development Goals.

Riassunto: Bollati I.M., Guerra C., Minacci L., *Le tracce dell'alluvione del 1978 in Valle Vigezzo: un progetto di Citizen Science nel Geoparco Globale UNESCO Sesia Val Grande.* (IT ISSN 0391-9838, 2023). Nelle giornate del 7-8 agosto 1978 un evento alluvionale significativo ha colpito la Val Vigezzo, localizzata nella parte nordorientale del Geoparco Globale UNESCO Sesia Val Grande (Italia Settentrionale). L'evento alluvionale, strettamente legato alle caratteristiche del substrato, è stato innescato da piogge intense e reso ancor più critico da un'urbanizzazione inadeguata. Tale evento ha lasciato profonde ferite nel paesaggio che stanno andando perdute. Allo stesso modo, profondi sono i segni impressi nella memoria della popolazione (residenti e turisti), specialmente nelle persone anziane. In questo articolo si descrive il progetto di Citizen Science dal titolo *I segni dell'alluvione del 1978 in Val Vigezzo: la popolazione racconta*. La raccolta dati è iniziata nel 2021 attraverso la partecipazione di residenti e turisti, ed è ancora in corso. Con il supporto e il patrocinio degli enti locali (e.g., Comuni) e in particolare dell'Ecomuseo Regionale 'Della pietra ollare e degli scalpellini' ('*Ed Leuzerie e di Scherpelit*' in dialetto locale), localizzato nel Comune di Malesco, un questionario online e in forma cartacea è stato somministrato per raccogliere sia informazioni sull'evento che immagini inedite, e per selezionare i siti in valle più significativi per i partecipanti in merito all'evento stesso. 34 sono i siti selezionati dai partecipanti e che verranno considerati per la creazione di una mappa di comunità e di un percorso diffuso sul territorio, per preservare tale patrimonio e trasmetterlo alle generazioni future. Il progetto di Citizen Science è anche in questa sede discusso in relazione agli Obiettivi dello Sviluppo Sostenibile (in particolare n. 4-9-11-13-17) dell'Agenda 2030 delle Nazioni Unite, anche rispetto alla localizzazione dell'area all'interno del Geoparco Globale UNESCO Sesia Val Grande.

Termini chiave: Eventi alluvionali, Geoparco Globale UNESCO Sesia Val Grande, Citizen Science, Obiettivi di Sviluppo Sostenibile.

INTRODUCTION

On 7th-8th August 1978, a serious flood hit the northwestern part of the Alps. One of the areas particularly affected, undergoing serious damage, was the Vigezzo Valley, located on the northeastern part of the Sesia Val Grande UNESCO Global Geopark (Northern Italy) (fig. 1). The Sesia Val Grande UNESCO Global Geopark (UGGp) is a relatively recent geopark; it was approved to be part of the Global Geopark Network in 2013 and covers a wide area (2,202 km^2), including a large variety of geological and geomorphological features (i.e. geodiversity; Perotti *et al.*, 2020). In the Sesia Valley sector (in the western part), the dominant features are the glacial landscape of the Monte Rosa Massif and the Sesia Supervolcano. On the other side, the Vigezzo Valley, in the Val Grande sector, was left free

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of glaciers tens of thousands of years ago and the main geological features which attract the interest of scientists are related to the bedrock. Pegmatite minerals have been studied in depth (Guastoni *et al.*, 2019) and the rocks, in general, attract attention because they are locally intensely deformed along important tectonic lines, such as the Insubric (or Canavese) Line, the Centovalli Line and the Fenecchio-Isorno Line (Tropeano *et al.*, 1999). The Centovalli Line strictly controls the trend of the main and minor valleys, generally in an E-W orientation. Due to the fragility of the fractured bedrock, covered by the incoherent strata of Quaternary deposits and soils (Bertamini, 1978: Pech, 1990; Dresti *et al.*, 2011), and the occurrence of extreme meteorological events, the area is often affected by hydrogeological instabilities (Dresti *et al.*, 2011; Bollati *et al.*, 2018), especially along the national road connecting Italy with Switzerland, used daily by cross-border workers (Cavinato *et al.*, 2005). During the 7th-8th August 1978 event, thousands of shallow landslides occurred, infrastructure was destroyed and the valley was temporary isolated (Tropeano *et al.*, 1999). The local population and tourists were emotionally hit by the event due to casualties (there were 15, but some people are still considered as being 'missing'; there were 20 casualties in the Ossola Valley; Ge, 1988), there was also the destruction of buildings and infrastructure. The scars in the landscape were impressive and some of them are still visible, despite the vegetation which has rapidly grown over them. What is really strong is the memory of the people who lived through the event, both residents and tourists. The residents suffered casualties, damage to houses, and losses to commercial activities, including those related to tourism. Tourists were temporarily trapped in the valley and, in some cases, were exposed to hazards. For instance, the campsite located along the banks of the Melezzo River, on an alluvial fan deposit, was flooded (Mortara and Turitto, 1989). Moreover, tourism-derived income was also impacted in the years following the event, especially affecting temporary visitors who were not staying in holiday homes (Ge, 1988).

After the event, the population reacted strongly, reconstructing everything (Mazzi and Pessina, 2008) and, after almost 10 years, 95% of the damaged assets had been refurbished, partly due to special laws which addressed funding (Ge, 1988). Several technical investigations were undertaken to map the effects of the disastrous event and to better define the geological and geomorphological factors predisposing area to such events (Tropeano *et al.*, 1999; Bertamini, 1978; Anselmo, 1979; 1980; Gandino *et al.*, 1980). Moreover, in 2008, on the 30th anniversary of the flood, Mazzi and Pessina (2008) published a book, including a collection of pictures and the eye-witness accounts from people who lived through the event. On the 35th (2013) and 40th (2018) anniversaries, thematic showcases and religious commemorations were also organised. Since the physical landscape is gradually losing the signs of such an event, and people who lived through the event are getting older, the Citizen Science project (named *The signs of the 1978 flood in the Vigezzo Valley: the population tells* (*I segni dell'alluvione del 1978 in Valle Vigezzo: la popolazione racconta*) is aiming to collect more systematic memories, through an online and paper survey as a first phase, and then through direct interviews and periodic meetings with the population as a second phase. The idea is to preserve memories creating a diffuse path on the territory, collecting iconographic material, linking (virtually) the places indicated by citizens who identified them as being most representative of the event.

The Municipalities of the Vigezzo Valley and surroundings have been directly involved, as well as the Unione Montana Valle Vigezzo, the Val Grande National Park, and the Sesia Val Grande UGGp, who provided sponsorship for the initiative. The Regional Ecomuseum 'Of the Soapstone and of the Stone-cutters' ('*Ed Leuzerie e di Scherpelit*' in local dialect), located in the Malesco Municipality (one of the seven Municipalities of the Vigezzo Valley), played a particularly active role by performing interviews with the local population.

In this paper the results of the first three years of data collection are presented and the potential contribution to the achievement of United Nations Sustainable Development Goals (UN SDGs) in the Sesia Val Grande UGGp are discussed. Indeed, in the literature, Citizen Science (CS) projects are recognised for the potential they have for the delivery of the UN SDGs (Fraisl *et al.*, 2020; 2022; 2023; Schleicher and Schmidt, 2020; Dörler *et al.*, 2021; Moczek *et al.*, 2021). In this specific case, the contribution to different SDGs could be meaningful, e.g. in relation to disaster risk reduction. An analysis of how CS projects in Geosciences, in the wider framework of environmental and ecological sciences, could contribute to the achievement of UN SDGs in UGGp is provided in the following section.

Citizen Science, United Nation Sustainable Development Goals and UNESCO Global Geoparks

Citizen Science can be defined as "Scientific activities in which non-professional scientists voluntarily participate in data collection, analysis and dissemination of scientific projects" (Haklay, 2012 and the references therein). Fraisl *et al.* (2020) summarised this practice in three phases: public participation, voluntary contributions, knowledge production. The definition of CS provided by the National Geographic Encyclopedia, reported in Haklay *et al.* (2021), is even more suitable in the present case study: "Citizen Science is the practice of public participation and collaboration in scientific research to increase scientific knowledge. Through Citizen Science, people share and contribute to data monitoring and collection programs". The need for integrating official datasets and combining data sources (traditional and non-traditional) about an event is a strong push for this kind of activity (Fraisl *et al.*, 2023).

Haklay (2012) identified four levels of CS, according to the participation and the engagement of volunteers, starting from level 1 (crowdsourcing), through level 2 (distributed intelligence) and level 3 (participatory science), as far as level 4 (extreme CS). The case study presented here may be located between level 1, i.e. a "contributory project, usually designed by scientists, and volunteers are involved mainly to contribute data" (Shirk *et al.*, 2012), and level 2, i.e. a "collaborative project, usually designed by scientists, and volunteers are involved to contribute data, but also support project design, data analysis, and/or dissemination of results" (Shirk *et al.*, 2012).

As highlighted in the literature (Schleicher and Schmidt, 2020; Haklay *et al.*, 2021), a higher degree of participation is afforded if the topic reflects the everyday life of participants. A CS project related to local population interests and concerns could be even more successful. Schleicher and Schmidt (2020) underlined how a positive outcome for participants could come from the learning and the increasing of the awareness of local problems and through the emotional and personal experience involvement. In this framework, giving value to indigenous knowledge, the voice of local communities becomes fundamental (Fraisl *et al.*, 2023).

With this aim, the types of people who will be interested in the project (and potential local facilitators, who can act as a link between the project promoter and local communities) have to be identified. The facilitators or stakeholders are expected to have the appropriate expertise to be able to involve the local population in the project (Paul *et al.*, 2018). In the case study, this role of 'facilitator' is being played by the Regional Ecomuseum '*Ed Leuzerie e di Scherpelit*'.

According to several authors (including Fritz *et al.*, 2019; Frails *et al.*, 2020), the space and time dimension of a CS project are also crucial in justifying citizen involvement (i.e. Completeness and Timeliness; Fraisl *et al.*, 2020). Space is crucial because CS projects may afford a greater spatial coverage to data collection, also in places difficult to reach (e.g., alpinists can reach remote places and collect data; e.g. Pelfini and Leonelli, 2014). Time is also relevant because the frequency of data acquisition may increase through the help of citizens. Fraisl *et al.* (2022) underline that, indeed, the importance of local people who have an indigenous knowledge, dating back to a time when instrumental monitoring (for example) had not yet been started.

The dissemination of the CS project results to the population is essential (Shirk *et al.*, 2012; Haklay *et al.*, 2021) and this addresses education, community empowerment and personal fulfilment, as well as an increase in awareness about local issues, and policy impacts on environmental topics. In particular, Paul *et al.* (2018) examined the case of CS being used for mitigating hydrological risk scenarios and building more resilient behaviour. For this specific case, the authors identified three disaster-cycle phases: pre-disaster preparedness, in-disaster response, and post-disaster recovery and adaptation. According to such phases, the present case study aimed to both collect information on a past disastrous event and analyse both the in-disaster response and post-disaster recovery, in order to maintain a memory of the causes and effects. This case study was also aimed at analysing and discussing the weak elements which played a role in the disaster.

All of these features of CS projects can be interpreted in terms of the 17 United Nations Sustainable Development Goals and the related 169 targets and indicators (Fraisl *et al.*, 2020). As previously mentioned, data acquisition may provide benefits to the achievement of SDGs too (Fritz *et al.*, 2019). According to Frails *et al.* (2020), 33% of the SDGs' 231 indicators can be supported through CS data. For the authors, five SDGs particularly benefited from CS contributions: SDG 3 (Good health and well-being), SDG 6 (Clean water and sanitation), SDG 11 (Sustainable Cities and Communities) and SDG 15 (Life on land). Schleicher and Schmidt (2020) also added SDG 4 (Quality education) and SDG 13 (Climate action) to these. Queiruga-Dios *et al.* (2020) indicated how a CS project, in particular, may contribute to the SDG 4 – Quality Education, allowing changing attitudes towards science and technology and improving scientific literacy. In relation to SDG 11 - Sustainable Cities and Communities, and SDG 13 - Climate Action, an important topic addressed by CS projects is favouring the improvement of a rapid disaster response (Fraisl *et al.*, 2020), especially if they are climate change related. This includes increasing citizen awareness about SDGs in general and promoting societal participation to enhance governance strategies against natural risks. Moreover, according to Bedessem *et al.* (2020), the importance of trusting in science, which may rise through CS projects, may help vulnerable territories to reduce disaster risk. This aim can be achieved through new knowledge, increased awareness and enabled learning (Dörler *et al.*, 2020), as well as partnerships, which is another SDG (SDG 17; Dörler *et al.*, 2020).

SDGs are currently becoming important targets within the framework of using UNESCO Global Geoparks (UGGps; https://unesdoc.unesco.org/ark:/48223/pf0000247741). As described by Gill (2017), geology is strictly related to SDGs, with regards to access to clean water and safe sanitation, food security and agro-geology, disaster risk reduction, energy supply and management, improved infrastructure and access to basic services, such as environmental and biodiversity management and conservation. As highlighted in the literature, sustainability education is one of three main pillars of UGGps, as well as geotourism and geoconservation (McKeever and Zouros, 2005; Catana and Brilha, 2020). One of the main focal points in UGGps is Education (SDG 4 – Quality Education; Catana and Brilha, 2020; Silva and Weber, 2018), where types of formal (schools) and non-formal (Geotourism) education activities are constantly proposed and renewed. Catana and Brilha (2020) surveyed the pursuit of SDGs in several UGGps, obtaining that SDGs other than SDG 4, significantly related to UGGPs actions, are, in descending order, SDG 15 (Life on land), SDG 11 (Sustainable cities and communities), SDG 13 (Climate change), and SDG 3 (Good health and well-being). In this last case, the outdoor activities practiced in UGGp are particularly effective (Bollati *et al.*, 2023a; 2024). The path towards SDG contributions by Geoparks is constantly empowering, including SDG 17 (Partnership), due to the existence of a Global Geoparks Network. Moreover, different geological backgrounds bring geologists with different interests to other geoparks, interacting with other people (partnership) according to geodiversity features. In UGGp, activities related to SDG 5 (Gender equality) reinforce the position of women, and SDG 8 (Decent work and economic growth) allows the creation of working opportunities for the local population. In the Global Geopark Network, moreover, a specific working group on SDGs has recently been created (Catana and Brilha, 2020) and, in 2023, a form was released to help UGGp managers to effectively quantify these contributions (https://globalgeoparksnetwork.org/?p=8535). Some CS projects have already been experienced within UGGp, with the aim of taking care of a geosite, reporting threats and damage to the site itself, and contributing to the long-term documentation of geosites (Albers *et al.*, 2017; in the TERRA.vita UGGp). Some of these projects have also been tested on geological heritage at a national scale (e.g. in Spain, 'Watch over a rock' or 'Adopt a geosite'; Vegas *et al.*, 2018). CS projects in UGGp can be useful in UGGp, by contributing to SDGs, particularly SDG 4-Qualitiy Education and SDG 11-Sustainable Cities and Communities.

The present CS Project, developed within a UGGp, will also be described in relation to the achievement of the SDGs.

THE STUDY AREA AND THE 1978 FLOOD EVENT

The Vigezzo Valley is located in the most eastern sector of the Sesia Val Grande UGGp (fig. 1a), at the border between Italy and Switzerland. Its natural prosecution in the Swiss territory is the Centovalli (fig. 1b and 1c). The Vigezzo Valley is elongated and follows the tectonic Centovalli Line (part of the system of the Simplon Line), which is responsible for the uplift of the deepest tectonic units of the Alps, in the so-called Lepontine Dome region (Steck *et al.*, 2013) (fig. 1c). The valley shows a strong structural control, with peculiar water drainage developing in two directions. The Eastern Melezzo (also named 'Melezza' by the Swiss) drains the Vigezzo and Centovalli towards the East, flowing into the Maggiore Lake near to the town of Locarno (Canton Ticino, Switzerland). The western Melezzo flows towards the West, into the Toce River near Domodossola city, this one reaching the Maggiore Lake at Fondotoce (fig. 1b). The water divide between the two 'Melezzos' is located in the middle of the Vigezzo valley bottom, near to the Santa Maria Maggiore village (830 m a.s.l.). The Melezzos collect water from some of the tributaries along the Vigezzo Valley and Centovalli, among which, on the Italian side, are the Rio Ragno, Rio Sasso, Rio Riana, Rio Rido, Rio Crosa, Isornino, Loana, and Rio Motto, which can be potential locations of debris flows under specific conditions. The geological map (fig. 1c) clearly shows the narrow alternation of geological units across the Centovalli and Insubric Lines. The predominant rock types which outcrop are the gneiss of the Pennidic and Austroalpine units, and the mafic and ultramafic rocks of the Pennidic and South Alpine units, intercalated with outcrops of Triassic and Jurassic sedimentary rocks. Along the Insubric Line, very evident levels of mylonites also crop out. Beside pegmatite minerals (Guastoni *et al.*, 2019), scientific studies mainly concern the valley and its relationship with the fragile and ductile deformation affecting the bedrocks. This is derived from the interaction of a single major dextral shear zone, in the context of the Centovalli line and the Rhone –Simplon stress field, and backthrusting along the Insubric Line (Surace *et al.*, 2011). Lacustrine and glacio-fluvial deposits of Eemian Age (67,000-120,000 years BP, or the Riss-Wurm interglacial) (Surace *et al.*, 2011, Steck *et al.*, 2013) filled a pull-apart basin with dextral shear, elongated along the main valley. The local retrieval of fossil leaves within the Quaternary deposits testified as to the different environment, whose genesis was also favoured by the accumulation of debris coming from mass wasting events along the slopes, and dated back to the Riss-Wurm interglacial, which partially obstructed the water flow (Sidler and Hantke, 1993). An interesting note was made by Sidler and Hankte (1993), underlining how extreme events like that of 1978 allowed for the denudation of the stratigraphic sequence, related to the Vigezzo Lake genesis. During the Quaternary, the glacier flowed from the Toce Valley to the Ticino hydrographic basin (Hankte, 1987; Kamleitner *et al.*, 2022) into the Maggiore Lake basin, following the pre-existing incision of tectonic origin along the Centovalli Line (Hankte, 1987; Sidler and Hankte, 1993). Terraces still testify as to the different incision stages exploited by the glaciers and rivers over time (Geissbühler, 1967). The terraces along the main valley, e.g. the ones on which the Villette and Coimo villages are located, were usually preserved during the floods affecting the valley bottom.

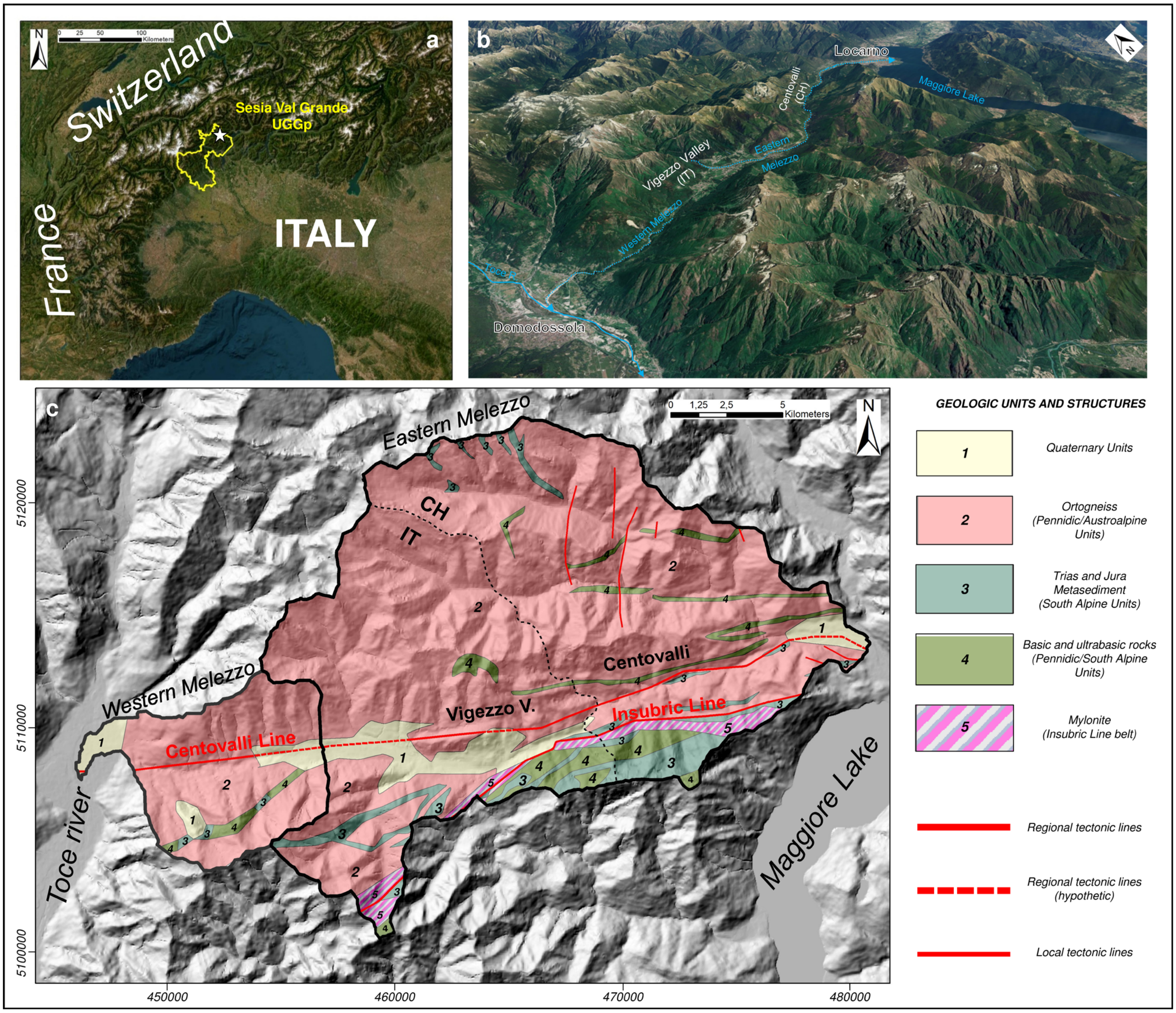

Figure 1 - The Vigezzo Valley location. a) location in Northern Italy, within the Sesia Val Grande UNESCO Global Geopark; b) 3D view of the Melezzos hydrographic basin (Google Earth); c) geological map of the area derived from the Swiss geological map (1:500,000; source: swisstopo service), drawn on the hillshade (source: Geoportale Regione Piemonte), with the Eastern and Western Melezzo hydrographic basins. Coordinate system is WGS 1984 UTM, Zone 32.

In relation to the geological and geomorphological settings, extreme meteorological events impact the area and are able to induce hydrogeological instabilities, whose effects on vulnerable elements can be serious (Bertamini, 1975; Tropeano *et al.*, 1999; Società Meteorologica Italiana, 2014; Bollati *et al.*, 2018).

Details on the alluvial event under investigation are provided in the following section.

The flood of 7th-8th August 1978 in the Vigezzo Valley

As reported by Goodess (2013), according to the IPCC Working Group I definition, an extreme weather event is 'an event that is rare at a particular place and time of year' (IPCC, 2007). Indeed, what is rare in one place may not be considered rare in another. Hence, many of the indices used to define the extremeness of weather events are based on their underlying statistical distribution rather than fixed thresholds (Goodess, 2013). According to Goodess (2013) the increase in extreme weather events, as a response to climate change, is a plausible scenario, even if the increase in frequencies of heavy rainfalls and floods alone are quite difficult to be determined because of strict links to local conditions. The Ossola Valley is drained by the Toce River (the main collector of the Western Melezzo) and is one of the rainiest area of the Italian territory, according to the average rainfall values calculated by Anselmo (1979; 1980) for the time interval 1913-1970. In the Ossola Valley, the cold air mass from the North collides with the hot air mass from the Mediterranean Region, triggering heavy rains and storms (Anselmo, 1980; Germann and Zanini, 2020).

The extreme event in the Vigezzo Valley on 7th-8th August 1978 caused hydrogeological instabilities, including floods, lateral fluvial erosion, and several landslides, killing people and destroying infrastructure; it was responsible for damage in other valleys in the Western Italian Alps (e.g. Aosta Valley, Upper Sesia Valley, and Anzasca Valley). The event exhausted itself in Swiss territory, after having also affected the Onsernone and Maggia Valley, in the Ticino Canton (Museo di Val Maggia, 2020). Table 1 lists the most disastrous events reported as hitting the Vigezzo Valley since the XVIII century (Bertamini, 1975; Tropeano *et al.*, 1999; Società Meteorologica Italiana, 2014; Bollati *et al.*, 2018). Despite the fact that the 1978 event was not a unique destructive event in the area (the just previous one had occurred on 12nd-13th July 1961), it is still impressed on the memory of the people, who immediately started the reconstruction, showing highly resilient behaviour (Mazzi and Pessina, 2008).

Within ten years, almost 95% of the damaged assets had been reconstructed (Ge, 1988) through the support of specific laws that were approved to finance the reconstruction through funding (36 billion of lira, the old Italian currency; Ge, 1988). Within this framework, some signs of the event are becoming indistinguishable (fig. 2a), despite

Table 1 - Main events hitting the Vigezzo Valley (sources: Bertamini, 1975; Tropeano *et al.*, 1999; Società Meteorologica Italiana, 2014; personal data). The area indicated is limited to the Toce hydrographic basin and does not exclude that the event has hit a wider region. The events marked with * are listed, even if only very generic indications are provided at the Toce hydrographic basin scale, since the Vigezzo Valley was probably affected as well.

Date	Area	Effects
1297*	Toce hydrographic basin	
10th-15th October 1755	Toce hydrographic basin (Western Melezzo)	Floods of the Western Melezzo, river diversion, building damages, casualties
1827, Autumn	Vigezzo Valley and Isorno	Floods of the Western Melezzo and Isorno, serious damages also to defense works
15th October 1868	Toce hydrographic basin (Eastern Melezzo)	Eastern Melezzo flood
1896	Vigezzo Valley	Eastern Melezzo floods, serious damages
26rd-27th August 1900	Toce hydrographic basin (Eastern Melezzo)	Eastern Melezzo, Rio Cui and alluvial fan, Rio Ragno, Rio Riana
26th-27th August 1900	Vigezzo Valley and middle-lower Toce hydrographic basin	Destroyed bridges and watermills, floods of Rio Cui, Rio Albogno, Rio Ragno, several bridges and roads damaged
1902	Eastern Melezzo	Eastern Melezzo. flood, damages
1906	Western Melezzo	Western Melezzo flood, damages to defense works
1907	Western Melezzo	Western Melezzo flood, damages to defense works, river bottom over elevation
1918	Re (Vigezzo Valley)	Rio Motto flood
1921	Toce hydrographic basin	River and stream floods
24th September 1924	Eastern Melezzo	Rio Motto flood and Eastern Melezzo with serious damages of bridges and others mainly in Swiss territory
1928, end of October	Vigezzo Valley	Eastern Melezzo flood
1932, September	Re (Vigezzo Valley)	Rio Motto flood
27th May 1951	Vigezzo Valley	Melezzos floods, 6 building damaged, destroyed railway
1951, middle August	Vigezzo Valley	Several storms, Melezzos floods, destroyed railway
21st-22nd August 1954	Toce hydrographic basin	Floods of Toce and tributaries, fluvial erosion and river diversion
16th April 1957	Western Melezzo	6000 m^3 landslide block the Western Melezzo
22nd February 1961	Western Melezzo	High sediment load and river bottom over elevation
12nd-13th July 1961	Vigezzo Valley	Floods of Eastern Melezzo, Rio Ragno, Loana, Isornino, landslides, destruction of bridges, buildings and railway
22nd-23rd August 1965	Vigezzo Valley	Landslides and floods
2nd-3rd November 1968	Vigezzo Valley	Landslides in Re, Gagnone, Paiesco; high sediment load of Rio Sasso
October 1975	Toce hydrographic basin and Vigezzo Valley	Moderate damages
6th-8th October 1977	Toce hydrographic basin	Floods in the Toce river and tributaries, several damaged bridges
7th-8th August 1978	Anzasca, Isorno, Vigezzo Valleys	Night storm, floods, buildings, railway and roads destruction
1979, middle October	Toce hydrographic basin	Landslides
13th-16th October 2000	Toce hydrographic basin	Various damages
11-12th November 2014	Toce hydrographic basin	Landslides in Re Municipality
2nd-3rd October 2020	Toce hydrographic basin	Floods and landslides

the fact that the local population are not in a hurry to forget what happened (Ge, 1988) and vegetation is progressively hiding the scars in the landscape.

According to several authors, in this case, the predisposing factors (including the susceptibility of the bedrock to landslides of different types, relating to fracturing and the presence of loose sedimentary coverage), played a fundamental role by amplifying the effects of the extreme meteorological event (Bertamini, 1978; Pech, 1990; Tropeano *et al.*, 1999). Prolonged rainfall over the previous three weeks had prepared the area to be triggered by further precipitation (Anselmo *et al.*, 1979; Tropeano *et al.*, 1999) and related flash floods when the water was suddenly released (Anastasi, 2020). Indeed, the pervasive water circulation in the fractured bedrock, together with the superficial soil and debris saturation, favoured diffuse landslides, locally increasing the solid discharge of streams. The role of vegetation was also considered in the scientific literature regarding the event but no distinctions were observed in the intensity of mass wasting, according to the spatial variation in the vegetation coverage (Bertamini, 1978; Anselmo *et al.*, 1980). Indeed, if vegetation contributes to the solid discharge of streams and rivers on one side, then, on the other side, vegetation can become a potential mitigation factor for torrential mass-movements favouring water infiltration below the surface, as analysed by Tiranti *et al.* (2016) in another area in the Western Italian Alps.

As mentioned before, the event occurred in one of the rainiest areas of the Italian territory (Anselmo *et al.*, 1980). In particular, the thermal difference between air masses coming from the North and South was really high during the event, and the very high temperature of the southern air mass increased the humidity in the region (Germann and Zanini, 2020). The trend of isohyets during the analysed 1978 event, developing NE-SW, overlaps very well with the annual average trend of rainfall. According to the same set of data, the extreme alluvial events, hitting the region in the time interval considered by the authors (1519-1978), reached the maximum frequency during August and showed a very local distribution (Bertamini, 1975; Anselmo *et al.*, 1980). An analogous trend was found by Donati (2020) for the nearby Canton Ticino, which was deeply hit by the same 1978 event.

Anselmo (1979; 1980) considered three weather stations, in order to analyse rainfall data from the event: Domodossola (fig. 1c), Larecchio and Palagnedra, the latter being in Swiss territory (in the Centovalli), where a hydroelectric power dam is located. At the Palagnedra station, in particular, a very low atmospheric pressure was recorded (Anselmo *et al.*, 1980). According to Anselmo (1979; 1980), the data recorded at the Domodossola weather station corresponded to a more than centennial return time for the 3-6 hour and 12 hour rainfall values, and 50 years return time for the 1 hour record. The recorded values are reported in table 2.

To compare these rainfall values with those recorded in the area in recently, we considered two automatic weather stations, currently measuring the values of rainfall and temperature. They are located in Arvogno (1,240 m a.s.l.; time frame: 2002-2023), at the head of the Eastern Melezzo watershed, and Druogno (831 m a.s.l; time frame: 1990-2023), in the Vigezzo valley bottom. Moreover, the Larecchio station, located just outside the Melezzos watershed but hit by the 1978 flood and recording during the event, has been reactivated too (1,860 m a.s.l.; time frame: 2000-2023) and is considered here. The data are presented in a Supplementary File.

The average monthly and total annual rainfall values are as follows: Arvogno - 121.2 mm and 1,453.3 mm; Druogno - 129.483 mm and 1,569.34 mm; and Larecchio - 170.81 mm and 2,082.93 mm. Considering the Arvogno automatic weather stations, the monthly rainfall values are above average (121.1 mm) from April until October, with the maximum monthly rainfall value being recorded in May (209.13 mm). At the Druogno station, the average monthly rainfall (129.48 mm) is overcome from April until November, excluding July, with peaks in May (183 mm), October (188.85 mm) and November (192 mm). At the Larecchio station, the average monthly rainfall (170.815) is overcome from April until June, and then in August, October and November (maximum 307 mm).

The daily values are comparable to those recorded during the 7th-8th August 1978 flood event at the three stations (223-275 mm; Anselmo 1979; 1980), and were recorded on 2nd October 2020 in Arvogno (234.4 mm), on 20th September 2000 in Druogno (223.8 mm), and on 4th November 2014 (235.2 mm), 20th September 2000 (221.6 mm) and 2nd October 2020 (221 mm) in Larecchio.

In the Supplementary File (table A1), the daily values exceeding 6% the Mean Annual Rainfall (MAR) (Luino, 2005) are also listed. According to Luino (2005), the 6% MAR overwhelming can be related to potential conditions of instabilities for debris flow in contexts that are analogous to the case study. Indeed, they have already been considered for analysis in one of the Eastern Melezzo tributary basins (Bollati *et al.*, 2018). Among the listed events, in the time interval covered by the stations, only the October 2000 and October 2020 events, recorded in all three of the stations, are reported as being damaging in table 2. During these events, strong floods hit the Toce hydrographic basin (Bollati *et al.*, 2023a). At the Arvogno automatic weather station, a rainfall value comparable to 7th August 1978 (234 mm) was recorded on 2nd October 2020, followed by values lower than 200 mm.

Several other events exceeded the 6% MAR values but no damage was reported, according to the historical archives. For instance, at the Druogno automatic weather station, the maximum daily rainfall value was recorded on 20th September 2000 (223.8 mm), not in relation to any flood event in the study area, but more generically

Table 2 - Rainfall and water discharge data of the 7th August event, modified from Anselmo (1979; 1980) and integrated with data from Bertamini (1978) and Carcano and Bocchiola (2015).

Meteorological station	Hydrographic basin	Altitude (m a.s.l.)	Rainfall (mm) 1h	3h	6h	12h	7th Aug.
Domodossola (Centrale Calice, ENEL)	Toce	277	50	138	190	205	223
Larecchio (SISMA)	Isorno	2,126	58	134	172	202	230
Palagnedra (O.I.M., RIMA, 1979)	Eastern Melezzo	495	65.5	117	155	232	275
Water discharge section	Hydrographic basin	Altitude (m a.s.l)	Surface (km^2)		Water discharge m^3/s	$m^3/(s*km^2)$	
Pontetto	Isorno	343	73		280	3.8	
Masera	Western Melezzo	296	52.7		300	5.7	
Gagnone		784	7		120	17.1	
Orcesco	Rio Ragno	823	5		80	16	
Zornasco	Isornino	800	13.3		150-200	11.3-15	
Crana	Eastern Melezzo	850	25.9		250-300	9.7-11.6	
Re		663	107		1,500	14	
Palagnedra		493	126		1,850-2,150	14.7-17.1	
Ponte Brolla	Maggia	254	592.6		2,200-2,600	3.7-4.4	
Solduno		215	926		5,000	5.4	
Candoglia	Toce	196	1,532		2,137	1.39	
Solid discharge section		Altitude (m a.s.l.)	Surface (km^2)		Solid discharge m^3/s	m^3/km^2	
Palagnedra		Eastern Melezzo	140		$2x10^6$	14,000	

in the Toce basin. At Larecchio, where on 7th August 1978, 230 mm were measured (table 2), comparable values were recorded on 4th November 2014 (235.2 mm), 20th September 2000 (221.6 mm), and on 2nd October 2020 (221 mm).

Considering the water discharge values, those calculated by Anselmo (1979, 1980) for the 7th August 1978 are also reported in table 2. The flood peak was reached at around 6 P.M. on the 7th August, when several bridges and the Ceretti hydroelectric power plant were completely destroyed. It is worth noting that the peak of the flood along the Toce riverbed was calculated to be 2,137 m^3/s (at the Candoglia hydrometric station), with respect to regular values before the floods (120 m^3/s) (Anselmo *et al.*, 1980) (table 2). The peak at Candoglia was reached at 8 A.M. on the 8th August. Different authors (Anselmo *et al.*, 1980; Carcano and Bocchiola, 2015) underlined how this value was lower than the water discharge recorded just 1 year before, during another extreme meteorological event (3,650 m^3/s; 7th October 1977; table 1). It is worth noting that the distance of the measuring station from the damaged areas could be relevant when assessing the effective power of a flood, due to potential lamination effects along a river, as well as temporary damming episodes. In the Swiss territory, the water discharge on 7th August 1978 in Solduno (Maggia hydrographic basin; table 2) was calculated as 5,000 m^3/s which, in this case, was higher than the maximum values recorded during a previous event (4,000 m^3/s; 24th September 1924) (Anselmo *et al.*, 1980).

Bertamini (1978) indicated that the greatest number of landslides (more than 50/km^2 in the upper Eastern Melezzo basin) occurred between 6.00 and 9.00 P.M. on the 7th August, with the peak being reached between 6.15 and 7.30 P.M. Several rock fall and sliding events occurred (fig. 2b) but even more shallow landslides (fig. 2c). Moreover, floods, over-bank deposition, lateral migration of the rivers and erosion along riverbanks (fig. 2d), as well as the reactivation of alluvial fans occurred too. These destructive processes were triggered by heavy rains which caused the upper strata of loose sediments to become saturated, having already been subjected to rain in the weeks before (Anastasi, 2020).

A density of 70-90 landslides per km^2 was calculated (technical report, Interreg II). As mentioned before, the vegetation coverage does not seem to have played a role in such instabilities, the latter being ubiquitous (Bertamini, 1978; Anselmo *et al.*, 1980). Otherwise, the fractured bedrock seems to have played a more effective role as a predisposing factor in this specific case, with respect to vegetation coverage, which was, instead, removed, becoming part of the mobilised debris, transported by water along streams (fig. 2e). In some cases, the water flow was blocked by natural or anthropic narrowing along the streams, corresponding with previous landslides (e.g. along the Fenecchio stream) or bridges or artificial stream coverages. This contributes to increasing the destructive power even more, triggering flash floods (Anselmo *et al.*, 1980). The high solid discharge value calculated at the Palagnedra site on 7th

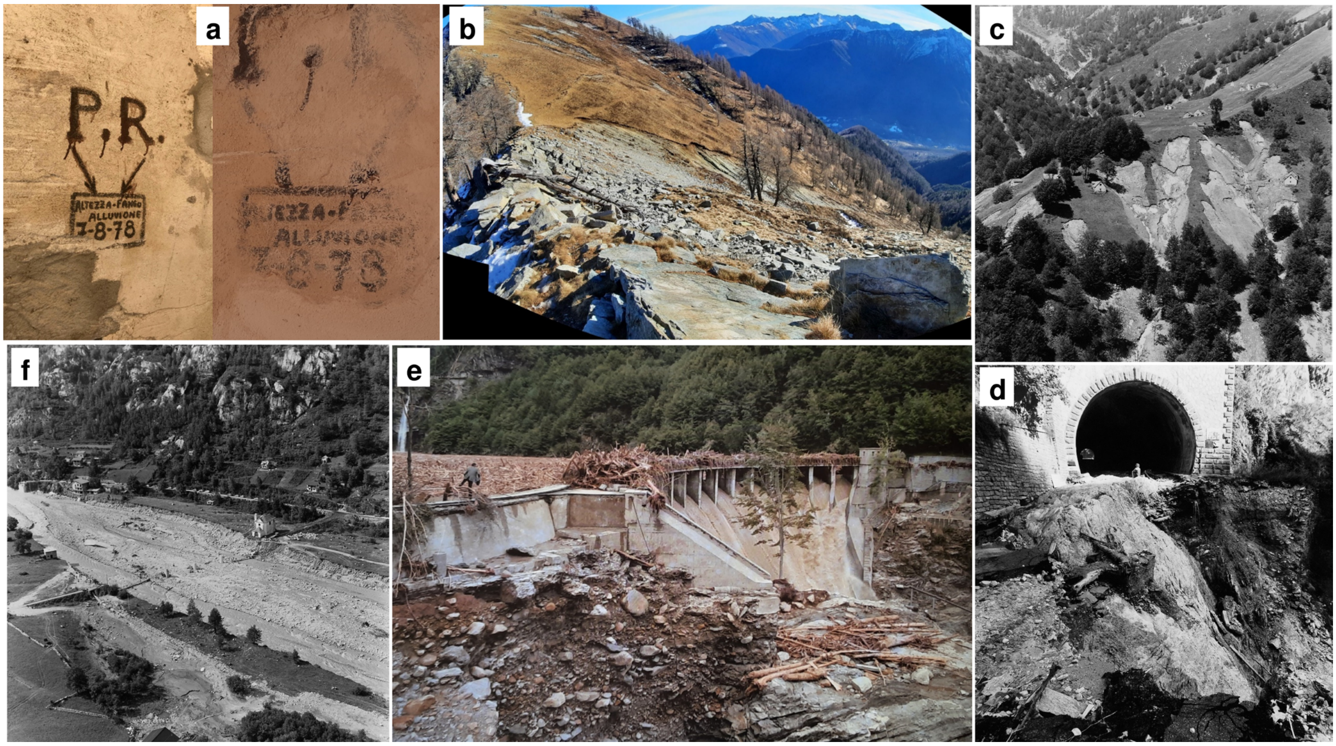

Figure 2 - Overview of the 7th-8th August 1978 event. a) Signs of the water and debris level reached in Via Maggiore (in the Druogno village), now getting lost due to building refurbishment; b) rotational landslide along the Monte Mater water divide of the Western Melezzo (2021); c) shallow landslides at the head of the eastern Melezzo, where 70-90 landslide/km^2 were recorded (technical report, Interreg II); d) lateral erosion and migration along the Eastern Melezzo, near the Gabbio church; e) the high solid discharge, rich in wood, at Palagnedra dam; f) the interruption of roads from the Vigezzo valley to Domodossola city, also due to flooding of the tunnel. (fig 2c, 2d and 2f: pictures courtesy of C. Pessina; and fig. 2e: source Swiss Dams, 2017).

August 1978 (2 x 10^6 m^3; table 2; fig. 2e), indicates the occurrence of damming episodes by rocky and woody debris collecting along the main rivers and tributaries, with flash flooding episodes. The effects of such floods were recorded as far as the Maggiore Lake where a lake level rise of 1.2 m was measured in 12 hours (Anastasi, 2020). Moreover, it is important to consider the off-site effects of these kinds of events, as the solid discharge disturbed the chemical and biological equilibria of the lacustrine basin, potentially in the long term (Ambrosetti *et al.*, 1980).

Globally, the disastrous event provoked economic damages estimated to be about 80 billion lira (the old Italian currency) (Regione Piemonte, 1978): roads, railways, bridges and tunnels were completely destroyed by floods and landslides and submerged, if located within the bankfull width and along the riverbanks (fig. 3).

Moreover, different kinds of bridges resisted the floods differently and, in some cases, older ones demonstrated a better response (Anselmo *et al.*, 1980). According to Anselmo (1980), the destruction was even worse due to increasing human expansion on the territory. In particular, building on alluvial fans (fig. 3a and 3c), inside the bankfull area (fig. 3a) or modifying and covering the streams inside villages (fig. 3d), as well as the inadequate hydro-forestry refurbishment along the slopes, were considered amongst the worst practices favouring instabilities. Anselmo (1980) underlined that these practices are preparatory factors and the extreme character of the rainfall event (representing the triggering factor) cannot be considered the only thing responsible for such a catastrophe.

MATERIALS AND METHODS

Even if the memory of the 7th-8th August event is still clear in the minds of people who lived through it, the next generation may not learn of it (fig. 2a). The need to prepare for a state of emergency is crucial in terms of disaster and risk mitigation. For this reason, the CS project was presented to all the Municipalities of the Vigezzo Valley and surrounding areas (Craveggia, Druogno, Malesco, Masera, Re, Santa Maria Maggiore, Toceno, and Trontano Villette), as well as the Unione Montana della Valle Vigezzo, the Val Grande National Park, and the Sesia Val Grande UGGp, who provided sponsorship for the initiative. An active role was particularly played by the Regional Ecomuseum '*Ed Leuzerie e di Scherpelit*' located in the Malesco Municipality, one of the seven Municipalities of the Vigezzo Valley, who disseminate information about the initiative and is functioning as a facilitator.

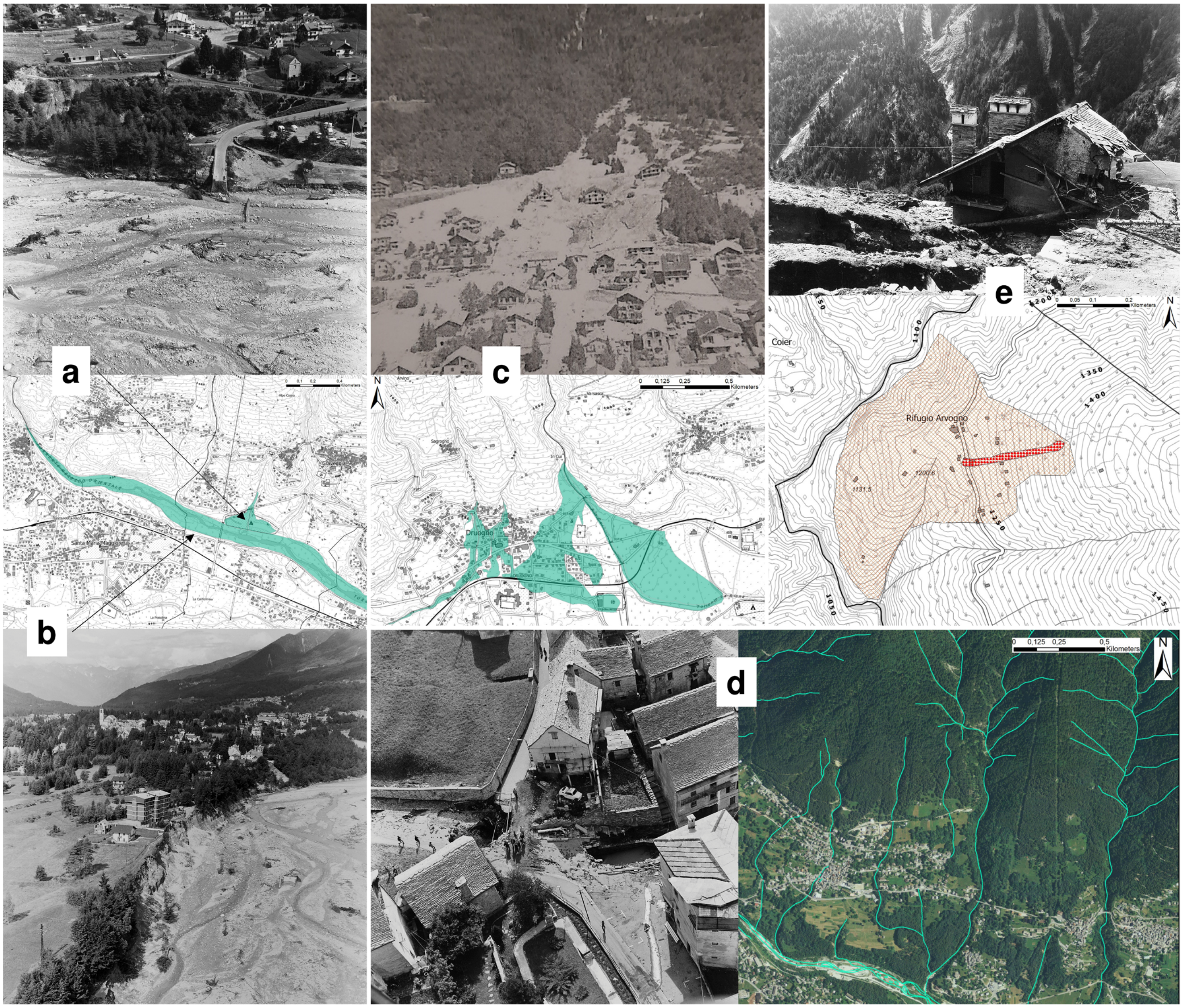

Figure 3 - Hydrogeological instabilities, geomorphological conditions and human settlements. a) Flooded camping, located in the bankfull of the Eastern Melezzo (green stripe on the topographic map) and on an active alluvial fan of a tributary (green polygon on the topographic map) (Site 10 in table 3; fig. 4); b) lateral erosion along the river bank of the Eastern Melezzo threatening a building located along the riverbank; c) reactivation of the Rio Cui alluvial fan (green polygon on the topographic map), on which part of the Druogno village is settled; d) blasting of the Rio Rido inside the village of Toceno, where the stream was buried, causing the death of 4 people; some of the buried streams inside the village are reported (light blue in the orthophoto) (Site 1 in table 3; fig. 4); e) debris flows (red stripe on the topographic map) and shallow landslides (red grid on the topographic map) affecting the Arvogno hamlet, which completely destroyed a restaurant, killing 1 person inside (Site 8 in table 3; fig. 4). The pictures in 3a, 3b, 3c, 3d and 3e are courtesy of C. Pessina; picture 3c is from Anselmo *et al.* (1980) and related sources. The thematic maps were realised using the shapefile and raster file from Geoportale Regione Piemonte.

During the summer of 2021 and 2022, an online survey was distributed. The form was accessible via mobile devices through a QR code placed on leaflets posted on various walls in the villages and shared through local Facebook groups in the Vigezzo Valley, as well as newspapers. Moreover, a specific Facebook page was created for the project. This type of dissemination can be crucial for CS projects (Fraisl *et al.*, 2022). A paper format was also prepared for those not accustomed to new technologies, especially older individuals who may find participation in CS projects challenging yet extremely valuable (Fraisl *et al.*, 2022). Given that the investigated events occurred over 40 years ago, it is expected that the majority of the information will come from elderly participants. The online and paper forms aimed to not only systematically collect information which is already known but, also, as yet unpublished pictures and material through spontaneous delivery to a dedicated email. Currently, the data collection is ongoing, since the available people are being interviewed in person, mainly via the Regional Ecomuseum ‘*Ed Leuzerie e di Scherpelit*’ (the facilitator). The aim of the Ecomuseum is to preserve the material and immaterial heritage of the territory, as well as to promote it with sustainable strategies. Moreover, the Ecomuseum is a strategic contributor to the deep knowledge of people living in the territory and their background. The Ecomuseum is in charge of collecting data (texts, pictures, etc.) and holds specific events, such as local meetings. In particular, because the Ecomuseum is very familiar with the local population, in the second phase of the project, it has also organised individual interviews, sometimes carrying out audio or video recordings.

If the technical data available for the event is abundant (even if mainly confined to grey literature) and the disastrous event opened up the way to new research and studies in the area, the feelings of the local population have been collected by Mazzi and Pessina (2008), or are lost in local newspaper articles, which duly dedicate a slot to remember the tragedy each year.

The structure of the survey included questions concerning the personal status of participants (age, education degree, provenance, resident or tourist status). In the first and second section, the questions specifically focused on the event, along with open questions. The first section allows for the background of respondents, which may be useful to understanding the relevance and meaning of the data (Fraisl *et al.*, 2022). The online version is still open to answer and, periodically, the paper surveys are collected by the local tourist agencies. Moreover, partially free interviews, including specific questions but mainly leaving respondents free to describe their feelings and memories, are still being conducted to collect even more witness statements, to enrich the knowledge about the event. In all cases, privacy issues and permission requests for reusing data and pictures have been explained to and/or requested of participants.

This study illustrates the data collected up to December 2023, showing the ranking of sites, as indicated by the respondents, and selected according to their preference and to the topic they represent. One participant could indicate more than one site. A list of sites was not created a priori but respondents could spontaneously propose their own sites. This has generated some issues in clearly understanding the sites and their location. Hence, a quality assurance stage for the data (including field and digital map surveys) was performed, as suggested by Fraisl *et al.* (2022). The list of sites presented, therefore, derives from a re-elaboration of the raw indications provided by the respondents, to identify the common places (by synonyms) and to exclude the places not described enough or not detectable in the field. Some very close sites have finally been merged, if suitable. Then, the precious witness statements collected from participants were compared and, in some cases, integrated with the technical reports of the effects and damage derived from the flood by local and regional entities.

RESULTS

Of the 83 respondents, 76% filled in the online version of the questionnaire and 24% filled in the paper version. The latter were compiled by older people (average age 67), while the online version was filled in by those with an average age of 55. This data is in agreement with the time passed since the event (43-45 years). The greatest number of respondents had been educated to a high school level (42%), followed by people with at least a Bachelor or Master degree (33%). The greatest portion of the participants (61%) were tourists (with long term holiday homes, or on excursions) and only 39% lived or worked in the Vigezzo Valley. Local residents are currently more likely to respond to the personal interviews. No significant differences were observed among the participants from the different Municipalities: in decreasing order, these were Malesco, Toceno, Santa Maria Maggiore, Druogno, Re, Craveggia, and Villette. Respondents from two Municipalities were missing: Masera and Trontano. Even if damage was reported in their territory, they are located far from the other villages, at the end of the Valley, near to the confluence of the Western Melezzo and the Toce. Moreover, the survey was dispatched a year after the project started (in 2022 rather than 2021). Both of these factors could have influenced the success of the initiative.

Ninety-six percent of respondents knew about the event, although about 24% were not present during the event, implying that they have heard about it through friends or relatives, or from newspaper and television news.

Thirty four places were spread over the different Municipalities, with one of them being located in Swiss territory (table 3), as indicated by the respondents. The latter usually indicated sites outside of their own Municipality. The average number of preferences given to the sites is 4 (4.8%), and 11 places are above this average (fig. 4). The minimum number of preferences is 1 (1.2%) and the maximum is 22 (26.5%). It is important to recall that one participant could indicate more than one site.

The most recurrent features of selected sites (table 3) are flooding (45% of the sites), followed by infrastructure destruction (41%) and casualties (36%); landslides were also frequently nominated (23%). Other features are related to the lateral migration and erosion of riverbeds (14%), issues along transport ways (9.0%) and artificial coverage of streams (9.0%), solid discharge (4.5%), water discharge (4.5%), water source modification (4.5%), resistance of infrastructure (4.5%), ground holes and religious beliefs (4.5%). One site may cover more than one feature.

Table 3 - Features of the places selected by participants and ranking according to the number of preferences received (see fig. 4).

ID	Place name	Topics
1	Rio Rido and commemorative plaque	Blasting of the artificial coverage of the stream Casualties
2	Malesco-Zornasco Bridge (Papa Giovanni XXIII Street)	Fallen bridge
3	Arvogno and the commemorative plaque	1 casualty
4	Commemorative plaque and Gagnone-Orcesco railway station	More than 1 casualties Unique access to the valley from Domodossola
5	Gagnone viaduct and bridge over the Western Melezzo	Damages to infrastructures
6	Druogno village and Municipality building square	Hole in the ground
7	La Vasca stream	Bridges affected by the flood
8	Caminetto commemorative plaque	Debris flow Casualty
9	Malesco-Re bridge	Fallen bridge
10	Prestinone bridge and Hermitage camping	Fallen bridge Flooded camping
11	Debris flows and shallow landslides in Arvogno area	Landslides
12	National road and Masera tunnel	Lateral erosion of Western Melezzo Flooded tunnel Casualties and missing people
13	Railway and viaduct on the Rio Loana, Malesco	Minor stream flood Fallen bridge
14	Sasseglio, Don Cleto house	Minor stream flood
15	Peschiera, Zornasco	Lateral erosion of Eastern Melezzo
16	Rio Ragno and Baitina	Debris flows
17	Santa Maria Maggiore Wood and Luna Park	Flood More than 1 casualty
18	Rio Isornino, Zornasco	Minor stream flood
19	Rio Cui	Minor stream flood
20	Monte Mater landslides	Landslides
21	Hydrometric level sign, Maggiore street, Druogno	Commemorative plaque Hydrometric information
22	Strada Crotta bridge	Minor stream flood
23	Albogno streams	Minor stream flood
24	Buttogno square and bridges	Minor stream flood
25	Ferruginosa water spring	Hydrogeological consequences
26	Commemorative plaque, Toceno, Church square	More than 1 casualty
27	Hotel Miravalle, Toceno	Blasting of the artificial coverage of the stream
28	Debris flows and shallow landslides in the head of Eastern Melezzo	Debris flows and shallow landslides
29	Railway and viaduct on the Rio Roula, Malesco	Minor stream flood Fallen bridge
30	Madonna del Gabbio church	Lateral erosion of Eastern Melezzo Fallen bridges Religious tradition
31	Railway bridge, Cottredo, Malesco	Fallen bridge
32	Maglione bridge, Re	Resistance of the bridge
33	Meis railway station	Flood
34	Palagnedra dam	Very high solid discharge (wood)

DISCUSSION

The CS project, which is still ongoing and whose preliminary data are presented here, has been built to give value to the personal experiences of participants and citizens related to the disastrous event which occurred on 7th-8th August 1978 in the Vigezzo Valley. Most of the information relating to the event has been taken from the grey literature and from technical reports. Most information was collected from people who lived through the event and this request for information has been seen as a reason to be proud of themselves. They were first involved in the data collection phase,

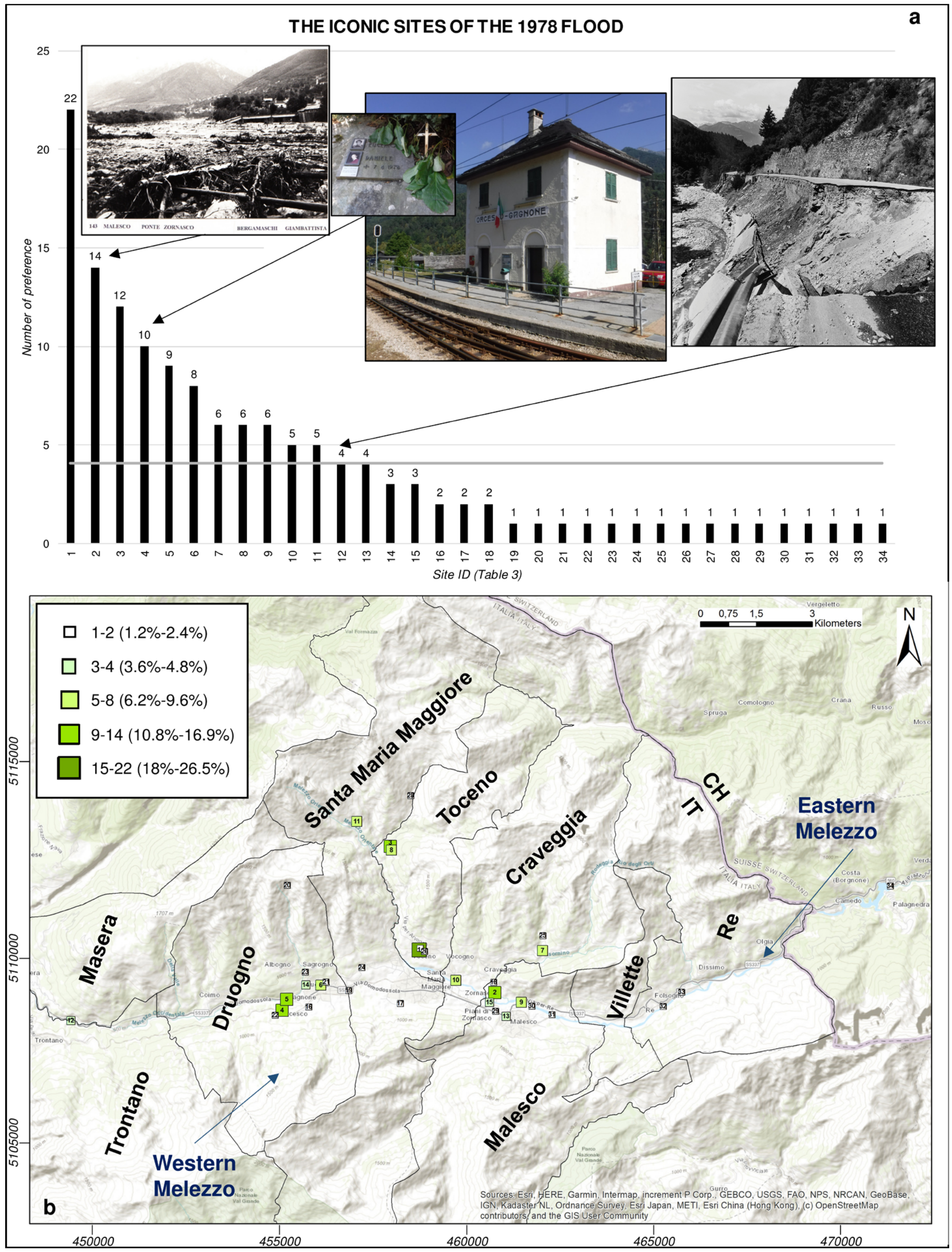

Figure 4 - Spatial and frequency distribution of the sites indicated by the respondents as being the most representative of the 1978 flood event. The numbering corresponds to the data in table 3, ranked according to the abundance of the indications. (a) The number of preferences are graphed with some pictures of sites depicting the variety of topics (Site 2, picture courtesy of L. Cavalli; Site 12, picture courtesy of C. Pessina). (b) The sites are mapped on the topographic base provided by ESRI, together with the Municipalities and the main streams. The coordinate system is WGS 1984 UTM, Zone 32.

immediately after the event in 1978, for technical reporting. Moreover, in the second phase of data collection, after more than 40 years, they were again called to indicate the signs of that event and to build a repository of memories for future generations. In the presented CS project, the time dimension is crucial because people (mainly old) who lived through the events have become a repository of intangible heritage; their past memories should not be lost (Fraisl *et al.*, 2022).

The presented project may also be framed in what is described by Paul *et al.* (2018) as CS dealing with hydrological risk reduction and resilience building. The most meaningful sites of the 1978 flood, which contributors unconsciously indicate, could be related to the most critical situations, in terms of the spatial relations between human infrastructure and settlements and the active geomorphological contexts (fig. 3). Casualties and damage are frequently listed. Among the sites over the average (table 3, fig. 3), that are exemplary for such critical situations, are: Site n. 1 and 6 (urban hydrographic pattern with partially covered streams); Site n. 10 (camping located on an active alluvial fan and within the bankfull); Site n. 3, 8, and 11 (lacking hydro-forestry refurbishment); Site 2, 4, 5, 7, 9, 10, 12, and 13 (fallen bridges, road and tunnel flooding for riverbed migration or widening). Building consciousness about the correct behaviour to adopt in a time of non-emergency, may help effective management during real emergency situations. This is possible through the explanation of what occurred in the past and how to mitigate its effects. For instance, under a severe flood the best way to survive is not to enter a road tunnel located adjacent to a flooding river (e.g. Site 12). In this case, it is a single citizen choice but, in other cases, the urban sprawl has resulted in people living in unsafe houses, located on covered streams, since new surfaces had been created for urbanisation new surfaces to be created for urbanisation (Site n. 1). As occurred recently in other Italian settlements, the most famous being Genoa City (Faccini *et al.*, 2015), the consequence of land use change and urban sprawl, combined with susceptibility to extreme meteorological events, potentially increasing in future because of climate change (Goodess, 2013), may create and trigger even worse scenarios.

The indications provided by the respondents, some of whom also sent original pictures, with respect to those contained in technical reports, are reported in the density map in fig. 5b, compared to the density map of damage collected in the Arpa Piemonte official database (fig. 5a).

According to Fraisl *et al.* (2023), the need for integrating official datasets and combining different data sources (traditional and non-traditional) could be one of the aims of a CS project. In these specific cases, we collected original pictures not shown before and, according to citizens' spontaneous indications, we extrapolated some of the sites included in the Arpa Piemonte technical database. The most meaningful places, which were worthy of observation, could be used as educational examples and carefully preserved. Moreover, the information retrieved until now has also opened the way for investigations into other events hitting the area (e.g. 1983), but not reported in the official lists (table 1). The continuation of the work will evaluate all of this novel and unpublished data. If a scientist, such as a geologist or a geomorphologist, is an indispensable figure for detecting and analysing causes and effects during an event like the 1978 flood (Anselmo, 1980), the citizen role is indispensable for completing the data collection, and even more so to extrapolate the information (i.e. a sort of heritage) they considered valuable to be preserved for future generations, such as this case. All of these procedures should be supervised and accompanied by scientists.

These practices acquire an even greater sense if performed in UGGp areas where, in relation to a bottom-up approach, the local population represents the motor but also the target of every initiative. As underlined by Gill (2017),

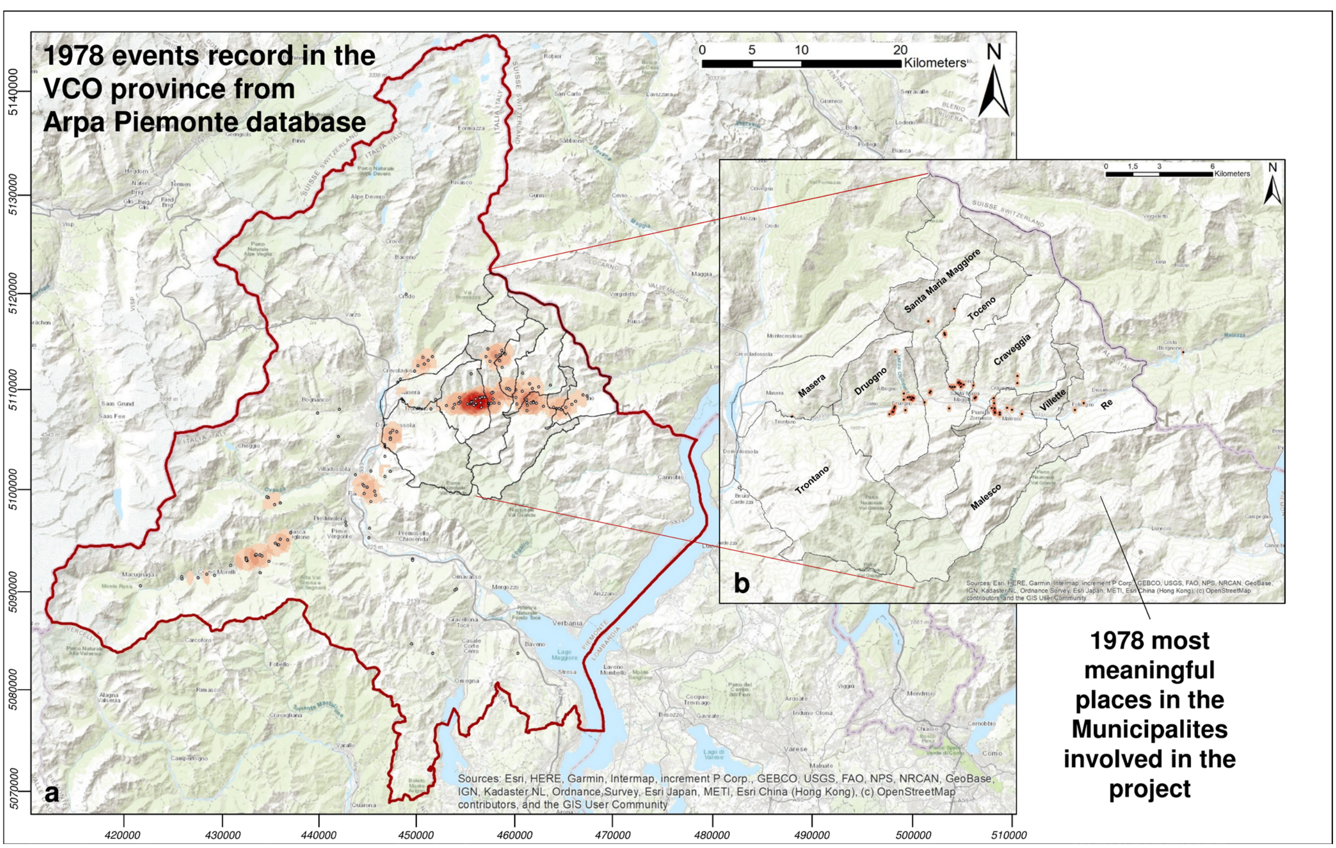

Figure 5 - Density maps of the damage related to the 1978 event in the Verbano-Cusio-Ossola province on the main map (source: Arpa Piemonte) (a), and density maps of the indications provided by the respondents in the square (b). The Point Density tool of ArcGIS was used to create the thematic charts. The coordinate system is WGS 1984 UTM, Zone 32.

“the importance of developing a location-specific contextual understanding (social, cultural economic, ethical environmental)” is crucial. For instance, participatory maps are a useful tool to engage local population in material product realisation, something they can feel theirs. The community or participatory maps, deriving from the evolution of the concept of the Parish maps (Clifford and King, 1996), are aimed at drawing cultural landscapes and showing interconnections between physical places, with hidden or forgotten stories. Haklay (2012) underlines how community or participatory mapping activity can be included in some way, as a form of CS. A community map of the studied event is the expected outcome, since it could be a way to fix it in people’s memories, the causes and consequences of such an event, helping them to be aware of the features of the territory they live in. Indeed, community maps, ideally collecting the places which are richly significant and elements of indigenous heritage, may also include, geological and geomorphological features, sometimes indirectly (Bollati *et al.*, 2023b).

In table 4, the SDGs to which the presented CS project could contribute are listed. The definitive contribution is expected at the end of the project and, currently, some of the SDGs have been identified as potential future goals.

This CS project is thought to stimulate cooperation between different Municipalities in the Sesia Val Grande UGGp. Moreover, having the event as a transboundary feature (Italy-Switzerland), the partnerships to achieve the goal (SDG 17; table 4) can be extended to natural features, accordingly, rather than administrative ones. Regional networking and improved communication between different nations is desirable and would contribute to SDG 17, as well as SDG 16 (Peace, justice and strong institutions; table 4). This would be empowered by cooperation across regional and local borders, as well as a bottom-up approach. The feeling towards this cooperation initiative could be even higher, since the Maggia Valley, one of the Swiss valleys hit by the 1978 event, has recently been hit by an analogous flood event, occurring on 29-30th June 2024, causing casualties.

Some of the SDGs listed in table 4 are strictly interconnected. In particular, SDGs numbered 4, 9, 11 and 13 meet on the project aim of increasing awareness about natural disasters, natural-related and human contributions. Specifically concerning SDG 4 (Quality Education), the creation of outreach and educational tools for people and school students could contribute to helping our knowledge of the factor predisposing, preparing and triggering hydrogeological risks in an area. This will help the population (participants and users of the thematic trail) to improve their behaviour during an emergency, as well as increase knowledge as to how climate change may influence future environmental disasters (SDG 13), since extreme meteorological events are expected to increase (Goodess, 2013). Understanding the relationship between territory features, extreme rainfall events, climate change, and related consequences, may stimulate the adoption of adequate lifestyles (SDG 4 – Quality education).

In the specific case of the 1978 flood event, the urban sprawl in hazardous areas contributed to the increase of risk scenarios (i.e. vulnerability and exposure) (Anselmo, 1980). Knowing how and where building resilient infrastructure in safe areas or, if already built, protecting them with adequate defence works (as a consequence of past disastrous events) is aligned with SDG 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable Cities and Communities). In the 1978 case, people showed strongly resilient behaviour and the restoration was almost completed (95%) over the following 10 years (Ge A., 1988, Ossola, Inchiesta, unpublished), through specific funding. Disaster risk reduction through education and memory survival will help, even if only marginally, with SDG 1 (No poverty) since, after a disastrous event, difficult conditions are common for the local population.

Concerning SDG 3 (Good Health and Well-being), the creation of a thematic/cultural trail to visit the places of the 1978 flood, will allow to stimulate physical activity in nature. If the excursion is guided, and if this thematic trail attracts even more visitors and schools from the area, opportunities to also contribute to SDG 8 (Decent Work and Economic Growth) become realistic. These SDGs will, potentially, only be addressed in the final phases of the project, when the community map and the trail will be realised and usable.

The CS project presented is still ongoing and is seen as a long-lasting project. Concerning future perspectives and the continuation of the project, some required actions can be listed, both for data collection and realisation of the final products.

- Continuing the interviews, mainly in person, contacting people directly through the facilitator. This is becoming necessary in order to reach the people who were not able to fill in the online form. These volunteers are expected to be aged and, therefore, not keen on new technologies or web interviews.
- Deepening knowledge about the other extreme events hitting the area but not reported in the analysed archives of events (but being mentioned by some participants) (e.g. 1983 is not reported in table 1).
- Opening the project to the Swiss territory (the Maggia and Onsernone Valleys) affected by the same flood problem (e.g. Museo di Val Maggia, 2020) to empower the partnership nature of the project (SDG 16, SDG 17).
- Organising meetings with local populations, to present the results of the project and to set up a round table discussion to collect even more suggestions and to work on community map creation (SDG 4, SDG 9, and SDG 11).
- Preparing the community map and the trail (virtual and in the field) with adequate material to enable school students to achieve a particular educational target (SDG 3, SDG 4, and SDG 8).

Table 4 - Sustainable Development Goals (SDGs) related to the CS project presented. They are not ranked in order of significance.

N.	SDG	Presented project	Connection with other SDGs
3	*Good Health and Well-being*	The creation of thematic/cultural trails allow to stimulate physical activity in nature	
4	*Quality Education*	Outreach and educational tools for school students and people regarding hydrogeological risks in the area	11-Disaster risk reduction through education 13-Knowledge about climate change influence on environmental disasters
8	*Decent Work and Economic Growth*	Opportunities for UGGp environmental guides to accompany people and school students in discovering the 1978 flood trail	4-Cultural/thematic trail realisation
9	*Industry, Innovation and Infrastructure*	Building resilient infrastructure (in safe areas or, if already built, protected with adequate defence work) as a consequence of past disastrous events	11 - Disaster risk reduction through education
11	*Sustainable Cities and Communities*	Disaster risk reduction through education and memory preservation	1-Defeating poverty potentially deriving from catastrophe
13	*Climate Action*	Understanding the relation between territory features, extreme rainfall events and climate change to be stimulated to adopt adequate lifestyles and urbanisation strategies	1-Defeating poverty potentially deriving from catastrophe 4-Increasing the resilience of local communities through education about disasters
16	*Peace, justice and strong institutions*	Cooperation across regional and local borders; community participation as bottom-up approach	17-Regional networking and communication improvement between different nations
17	*Partnerships to achieve the Goals*	The disastrous 1978 transboundary flood event as a chance for cooperation between neighbouring Municipalities/nations hit by the same catastrophe	16- Regional networking and communications improvement between different nations, to promote SDGs

CONCLUSIONS

The serious flood, which hit the Vigezzo Valley on 7th-8th August 1978 and was strictly related to bedrock features and triggered by heavy rains, was made even worse because of unregulated urban sprawl. In such conditions, the creation of awareness in local populations about the causes and factors influencing such kinds of risk scenarios become fundamental, in order to mitigate them. As demonstrated in the literature, CS projects contribute to the achievement of SDGs, which is particularly significant in a UGGp. The Citizen Science Project, named *The signs of the 1978 flood in the Vigezzo Valley: the population tells*, is still ongoing and is allowing the collection of data on intangible and tangible heritage related to the 1978 flood event. A crucial role is being played by the Regional Ecomuseum '*Ed Leuzerie e di Scherpelit*', acting as a facilitator in the survey distribution phase; it is now engaged in interview realisation and, in future phases, it will build the cultural offer about the 1978 flood. The community maps, that will be realised by considering the thirty four sites indicated and discussed to date, together with further indications emerging from future interviews and meetings, is one of the main outcomes expected from the project. These thirty four sites (indicated by the participants) are linked by critical relations between urban sprawl and geomorphological hazards. Several of the SDGs are related to the project. First of all, SDG 17 considers whether there is the possibility of enlarging the partnership to Swiss territory (since it was hit by the same event) will be pursued. Moreover, as mentioned before, education about natural disasters (including their predisposing, preparing and triggering factors, whether they are natural or anthropic) will contribute to SDG 4, SDG 9, SDG 11, and SDG 13, concerning quality education, building of sustainable cities and communities, and climate action. Indeed, if extreme events, such the object of this project, increase in the future, correct behaviour should be adopted by the local population, in order to prevent and then respond effectively to the emergency, afterwards.

SUPPLEMENTARY MATERIAL

Supplementary Material associated with this article can be found in the online version at: https://www.gfdq.glaciologia.it/index.php/GFDQ/libraryFiles/downloadPublic/5.

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