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L’apporto di Fausto Marincioni in questo lavoro di gruppo con i Geologi del CNR, è distribuito sull’analisi spaziale e valutazione del rischio, così come sull’intera scrittura e revisione del manoscritto. Un apporto prevalente nella scrittura lo si può trovare nella sezione: 2.2. Methods; 3.2. Urbanization and Hazard, e 3.3. Current Exposure to Geo-Hydrological Hazard.

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Article

Exposure to Geo-Hydrological Hazards of the Metropolitan Area of Genoa, Italy: A Multi-Temporal Analysis of the Bisagno Stream

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Abstract: Geo-hydrological risk reduction policies are becoming a critical challenge for environmental sustainability, both at the national and international levels. The reason is twofold: On the one hand, climate change has increase rainfall frequency and intensity, while on the other, reckless urban expansion has increased exposure to such hazards over time. Italy is a country that is very vulnerable to flood and landslide hazard; the city of Genoa, which, in recent decades, has been frequently hit by severe floods, has risen to symbolize Italian geo-hydrological risk. Recent studies on Genoa's geo-hydrological hazard have focused on the analysis of hydro-geomorphological features of the Bisagno stream basin, yet their main focus was on hazard control. Very little research has been done to enhance the understanding of the source of risk in such catchments. This paper presents a study on the increased urban exposure and vulnerability to geo-hydrological hazard along the Bisagno stream catchment area over the last 200 years. Morphometric analyses were coupled with historical documents showing the evolution of the urban layout in this area. The results show that the "Bisagno Master Plan", a territorial planning strategy aimed at reducing geo-hydrological hazard and risk, has not produced the expected benefits. In spite of the plan, critical changes in land use and the hydrographic network, along with uncontrolled anthropization of the Genoa metropolitan area, has continued over the last two decades.

Keywords: Bisagno stream catchment area; geo-hydrological hazard; urban sprawl; socio-economic vulnerability; city of Genoa; Italy

1. Introduction

Geo-hydrological hazards derive from the interaction between meteorological and geological processes, which can potentially cause casualties and the loss of exposed infrastructures [1–3]. During extreme rainfall events, the two most important hazards that can involve human settlements are landslides and floods. These two processes are very often interconnected and seem to follow a common evolutionary pattern [4]. Among the elements exposed to risk are the resident population, the structures (private and public properties), and the economic activities.

In recent years, dramatic river flooding has occurred in several regions of Europe, causing numerous casualties and damages reaching unprecedented proportions [5–9]. Similarly, landslides have occurred in different environmental settings across Europe; e.g., large rockfalls, rockslides, rock avalanches, and debris flows in the Alps and in other mountain ranges with steep slopes [10,11].

Indeed, the protection of human beings and capital assets from such hazards is high in the agenda of the European Union and is directly addressed by the European Regional Development Fund [12–14].

Italy is the European country with the widest areal distribution and highest recurrence of large landslides and floods, causing severe losses of lives and goods [15,16]. Data gathered from recent reports of the Research Institute of Geo-Hydrological Protection of the Italian National Research Council [17,18] show that, over the period 1964–2013, landslides and floods have caused 2007 casualties and 87 missing people. Such phenomena hit 2034 municipalities across the Italian territory, causing 25% of the total casualties from all natural hazards. In particular, over the decade 2004–2013, landslides and floods caused 215 deaths and 7 missing people. All Italian regions have suffered at least one landslide or flood event with fatalities [19,20].

Table 1 lists intense rainfall events that triggered catastrophic floods, flash floods, mud–debris flows, and shallow landslides that occurred in Italy since the year 2000.

Table 1. Fatalities caused by geo-hydrological events in Italy over the period 2000–2019. *Events in the Genoa Metropolitan Area are marked in italic.*

Event Day	Localities	Geographic Area	Fatalities	Event Type
23 November 2019	*Province of Alessandria, Genoa, Savona*	*Liguria, Piedmont (North Italy)*	1	Flood, landslide, mud–debris flow
21 October 2019	*Province of Alessandria, Genoa*	*Liguria, Piedmont (North Italy)*	2	Flood
3 November 2018	Casteldaccia (Palermo)	Sicilia, South Italy	9	Flash flood
27–30 October 2018	Dolomiti Bellunesi	Veneto, North Italy	2	Flood, landslide, mud–debris flow ('Vaia' storm)
12 December 2017	Lentigione (Reggio Emilia)	Emilia, North Italy	1	Flood
9–10 Sept 2017	Livorno city, Pisa city	Tuscany, Central Italy	8	Flash flood
31 October/1 Nov 2015	Calabria Jonica	Calabria, South Italy	1	Flood, landslide
15 October 2015	Sannio (Benevento)	Campania, South Italy	2	Flood, landslide
14 September 2015	Provincia of Piacenza	Emilia, North Italy	3	Flood, landslide
15 November 2014	*Province of Alessandria, Genoa, Milano, Savona, Imperia*	*Liguria, Lombardia, Piedmont (North Italy)*	*1*	*Flood*
9–10 November 2014	*Chiavari city, Leivi (Genoa)*	*Liguria, North Italy*	*2*	*Flood, landslide*
5 November 2014	Marina di Carrara	Tuscany, Central Italy	1	Flash flood
9–10 October 2014	*Genoa city, Montoggio*	*Liguria, North Italy*	*1*	*Flood, landslide, mud–debris flow*
2 August 2014	Refrontolo (Treviso)	Veneto, North Italy	4	Flash flood
3 May 2014	Senigallia, Chiaravalle (Ancona)	Marche, North Italy	1	Flood
18 November 2013	Province of Sassari, Nuoro e Oristano	Sardinia	18	Flash flood
11–12 November 2012	Massa e Carrara city, Maremma (Grosseto)	Tuscany (Central Italy)	7	Flood
22 November 2011	Provincia di Messina	Sicily (South Italy)	3	Flood
4 November 2011	*Genoa city*	*Liguria, North Italy*	*6*	*Flood*
25 October 2011	*Cinque Terre, Val di Vara (La Spezia)*	*Liguria, North Italy*	*13*	*Flash flood, landslide, mud–debris flow*
11 Jun 2011	Sala Baganza, Collecchio, Fornovo di Taro (Parma)	Emilia, North Italy	1	Flood
1–6 March 2011	S. Elpidio a mare (Fermo)	Marche, Central Italy	5	Flood

Table 1. *Cont.*

Event Day	Localities	Geographic Area	Fatalities	Event Type
1–2 November 2010	Province of Vicenza, Padova, Verona	Veneto, North Italy	3	Flood
5 October 2010	Prato city	Tuscany, Central Italy	3	Flood
4 October 2010	*Genoa city, Varazze (Savona)*	*Liguria, North Italy*	*1*	*Flood, mud–debris flow*
9 September 2010	Atrani (Salerno)	Campania, South Italy	1	Flood, mud–debris flow
1 October 2009	Giampilieri superiore, Scaletta Zanclea (Messina)	Sicily, South Italy	36	Mud–debris flow
18 July 2009	Valboite (Belluno)	Veneto, North Italy	2	Flood, landslide
22 October 2008	Capoterra (Cagliari)	Sardinia	5	Flood
29 May 2008	Val Pellice (Torino)	Piedmont (North Italy)	4	Debris flow
30 April 2006	Ischia (Napoli)	Campania, South Italy	4	Landslide
3 July 2006	Vibo Valentia city	Calabria, South Itaky	4	Flood
2 September 2005	Terracina (Latina)	Lazio, Central Italy	1	Flood, mud–debris flow
22 September 2003	Carrara city	Tuscany (central Italy)	2	Flood
8 September 2003	Palagiano (Taranto)	Puglia (South Italy)	2	Flood
29 August 2003	Val Canale and Canale del Ferro	Friuli (North Italy) and	2	Flood
24 November 2002	*Chiavari (Genoa)*	*Liguria, North Italy*	*1*	*Flood*
6, 23 November 2000	*Province of Imperia e Savona*	*Liguria, North Italy*	*7*	*Flood, landslide, mud–debris flow*
13–16 October 2000	Val di Susa, Canavese, Ossola	Piedmont, North Italy	23	Flood, landslide, mud–debris flow
10 September 2000	Soverato (Catanzaro)	Calabria, South Italy	13	Flash flood

Scientists have highlighted various factors triggering landslides and floods, from climate change [21] to land-use change [22–25] or stream power features [26].

The urban growth in Italy has increased significantly during the second half of the last century, but it was the heavy industrialization that followed World War II that produced the current urban tapestry. Unfortunately, much of this spread was carried out with poor planning and with very scarce attention, if any, to geo-hydrological processes [25,27,28]. Moreover, in some cases, this urban growth was based on incorrect assumptions. At the same time, as the urbanization proceeded, large areas devoted to agriculture were abandoned [29–31].

From this standpoint, the metropolitan city of Genoa has become an example for geo-hydrological risk, mainly because of two factors: (i) A hazardous location with intense and short-term precipitation due to the Genoa low cyclone [32,33], and (ii) reckless urban development not linked to the geological and hydro-geomorphological features of the river's catchments. The worst meteo-hydrological event of the area was logged on October 7th and 8th 1970 in Genoa, and it still maintains the record of rainfall height over 6 h (450 mm), 12 h (720 mm), and 24 h (950 mm) periods. Conversely, the cumulative rain record over 1 h (181 mm) was logged in Vicomorasso (located 8 km north of Genoa) during the event of November 4th 2011 (Table 1).

The Ligurian–Tyrrhenian hydrographic basins present widespread vulnerability [34], with buildings and infrastructures concentrated in the floodplains and along slopes. Many historical infrastructures, located along the strategic routes that connected the Mediterranean Sea with the Po river valley, were built on paleo-landslides. Among the river catchments flowing into the Tyrrenian Sea, the Bisagno

Valley is frequently studied because of the intensity and frequency of the meteo-hydrological events and because it contains most of the urban and suburban areas of Genoa.

The available literature is mainly focused on hydro-geomorphological hazards and much less on the vulnerability or possible risk reduction strategies; for example, meteorological and climatic aspects [35,36], land-use changes and run-off variations [25,37–39], hydro-geomorphological analyses of recent events [40–43], design and construction of the drainage ditches of the Bisagno stream [44–46], landslide hazard assessments [47,48], and management of geo-hydrological risk for civil protection and land-use planning [2,3,49]. Very little research has been done to explain how the urbanization patterns have defined the current conditions of geo-hydrological risk. It is worth mentioning here a few studies venturing into such analysis: (i) The European research project: 'Preparing for Extreme And Rare events in coastaL regions—PEARL' (http://www.pearl-fp7.eu/), in which the Bisagno valley was used as a study area to conduct research on socio-economic vulnerability [50], (ii) a study on the geomorphological evolution of the Bisagno valley over the last century, which highlighted the major anthropic origins of such changes [51], and (iii) a couple of studies focusing on infrastructures exposed to snow avalanches in the Austro-Swiss alpine areas [52,53].

This paper presents a study on the evolution of the urban layout of the Bisagno valley from the nineteenth century until present, during which the population of Genoa rose from 240 thousand to over 800 thousand residents, prompting the settlement of areas exposed to geo-hydrological hazards, thus increasing the overall disaster risk. Morphometric analyses were coupled with historical documents showing the evolution of the urban layout in the areas prone to floods and landslides. We hope that the analysis of the urbanization process of the metropolitan area of Genoa will provide new knowledge on current geo-hydrological risk and possible guidelines for a sustainable management of the overall area.

2. Materials and Methods

2.1. The Study Area

Genoa is one of the ten Italian metropolitan cities with an urban area of about 250 km^2, with about 600,000 residents. Furthermore, circa 1.5 million people live within a larger hinterland area, covering a total of 4000 km^2 located in the central part of the Ligurian coastal arc. Genoa is also home to one of the most important ports of Italy and Europe, serving as strategic passageway between Northern Europe and the Mediterranean.

The Bisagno stream catchment represents a rather large portion of the central-eastern sector of the city of Genoa (Figure 1). The surface of the basin is slightly less than 100 km^2 and reaches an altitude of 1036 m above sea level just 10 km from the coastline. The slopes are rather steep, with a mean gradient of about 50% with peak steepness of up to 75% and beyond.

The Bisagno is fifth order sensu Strahler in a hydrographical network characterized by a strong structural and geological control [54]. The lithology of the area is marly limestone flysch with shale interlayers and clayey shales as the base complex. Along the contacts between these rock formations, numerous springs (caused by the permeability contrast between the different rocks) and numerous landslides are present. The urban center of Genoa, in the terminal stretch of the Bisagno floodplain, is characterized by over-consolidated Pliocene clays, mostly located in graben-like structures parallel to the coastline [54,55].

Different strengths and deformabilities of the rocks cause widespread landsliding in the basin, although most movements appear localized along the boundary between the marly limestone flysch and clayey shales, yet no landslides are visible within the flysch formation. Furthermore, many of the slides located in the middle and higher segments of the Bisagno basin are characterized by Deep-Seated Gravitational Slope Deformation (DSGSD). Figure 2 shows the areal distribution, state of activity, surface extension, and numbers of landslides and DSGSDs.

About 34% of the surface of the Bisagno catchment area is affected by landslides, and the most common are shallow and complex large-scale landslides. The shallow ones are usually small in size

(30,000–40,000 m^2), first-time movements sensu [56], and triggered by heavy and short-lasting rainfall or less intense but prolonged rainfall [3,47,49]. Conversely, the complex landslides are usually massive in size (800,000–1,000,000 m^2), mostly inactive, and triggered by a morphoclimatic context that was different from the current one. From time to time, small portions of these paleo-landslides are reactivated (with very slow movements) by intense rainfalls, causing an increase in the level of groundwater: 'Residual state landslides' sensu [48,56].

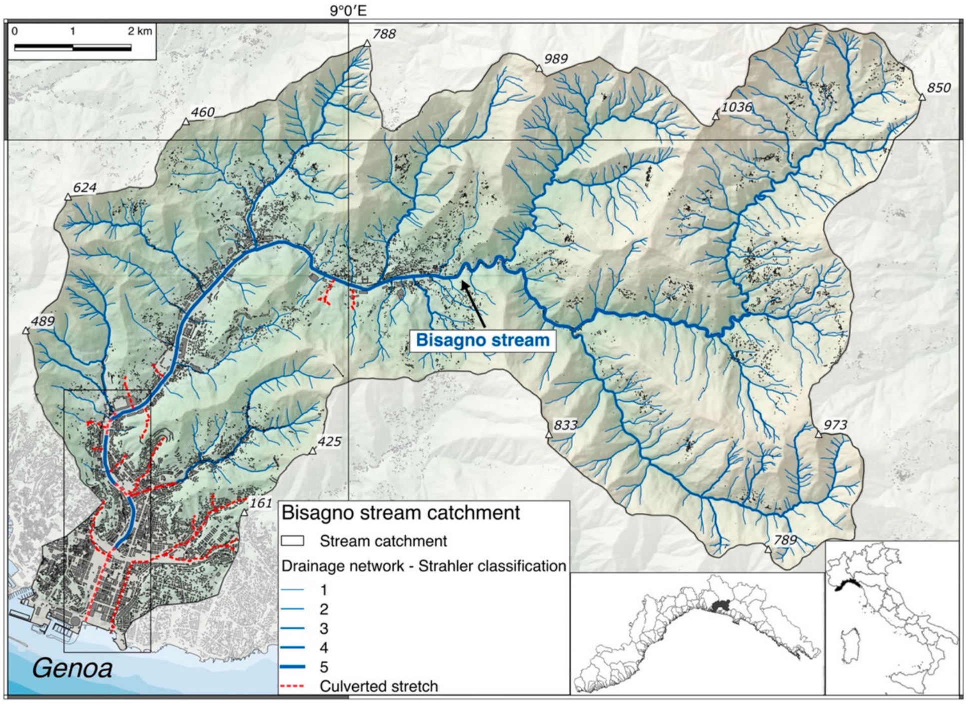
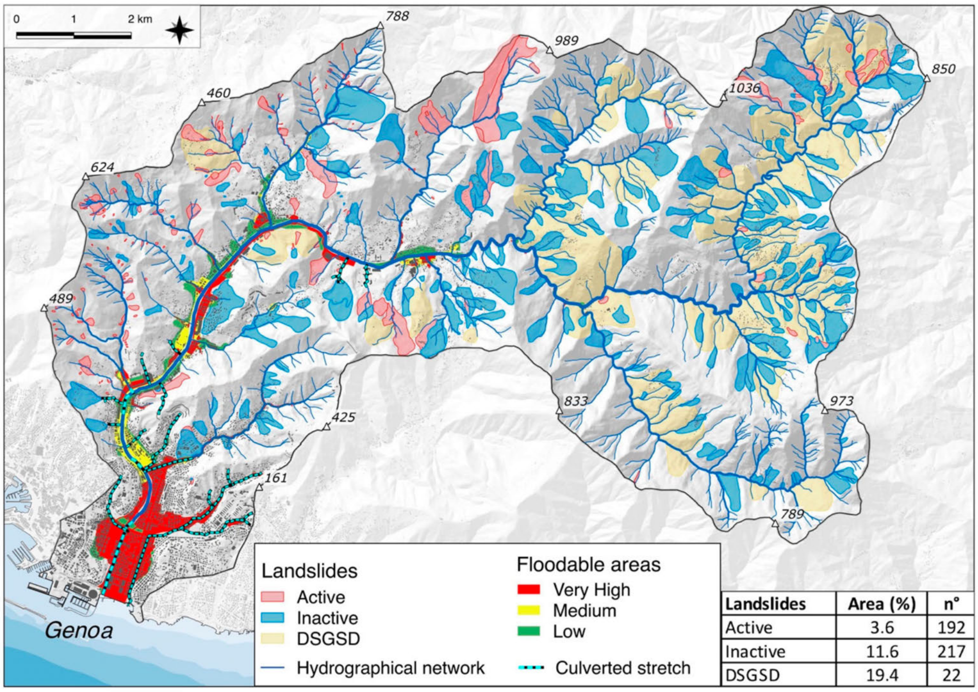


Figure 1. The studied area of the Bisagno Stream catchment; the final Bisagno stretch is shown in the box.



Landslides	Area (%)	n°
Active	3.6	192
Inactive	11.6	217
DSGSD	19.4	22

Figure 2. Landslides, Deep-Seated Gravitational Slope Deformations (DSGSDs), and flood-prone areas in the Bisagno stream catchment [57].

Figure 2 also shows floodable areas corresponding to the recurrent periods: 30–50 years (high flood hazard, 'red zone'), 200 years (medium flood hazard, 'yellow zone'), and 500 years (low flood hazard, 'green zone') [57]. Invariably, all of these areas are urbanized and highly populated.

The Bisagno catchment has been frequently subjected to geo-hydrological events: Table 2 shows data from the 20th century [25,51], albeit other destructive events happened previously, such as the Bisagno flood of October 1822. Noticeably, intense flood events began to happen after the construction of the 1.4 km final stretch culvert in 1929 [43]. Such ducts, because of an inadequate discharge capacity, caused the Bisagno water to be under pressure (no space was left for the stream to overflow). Even discharges with return periods of 30/50 years started to create problems [57].

Table 2. Geo-hydrological fatalities and damages in the Bisagno catchment area over the 1900–2019 period.

Storm Event Date	Rainfall Intensity	Discharge	Flood Events	Damage Losses and Other Damages	Storm-Related Deaths
10 October 1907	246 mm/24 h	500 m^3/s	Overbank flood Bisagno River flooded Molassana and Foce	Not quantifiable through historical sources	No casualties
18 July 1908	238.6 mm/12 h	420–450 m^3/s at Foce—the stream mouth	Overbank flooding. Bisagno River flooded in the upper and medium part of its catchment area	Damages not quantifiable through historical sources	No casualties
29 October 1945	285 mm/24 h	Lower Bisagno catchment and right slope, 202 mm/6 h. 450 m^3/s at Staglieno Cemetery	Flash flood Bisagno, Fereggiano, Veilino, and Geirato streams	Serious damage, today hardly quantifiable	5 fatalities
19 September 1953	206 mm/24 h, 486 mm/5 d	750–800 m^3/s	Flash flood Bisagno, Torbido, Geirato, Veilino, and Fereggiano streams	39 million Euros equivalent	No reports of casualties
8 October 1970	453 mm/24 h, 394 mm/24 h	950 m^3/s	Overbank flood Bisagno, Torbido, Geirato, Veilino, Fereggiano, and Mermi streams	55 million Euros equivalent; 1000 people homeless; 50,000 people left without jobs	10 fatalities in the Bisagno basin, 44 in Genoa metropolitan area
27 September 1992	435 mm/24 h, 337 mm/24 h	700 m^3/s	Flash flood Bisagno River	75 million Euros equivalent; 250 people homeless	No casualties in the Bisagno basin, 2 fatalities in the neighbouring Sturla basin
4 November 2011	166 mm/1 h, 499 mm/12 h	700 m^3/s	Flash flood Bisagno and Fereggiano streams	150 million Euros; 150 people homeless	6 fatalities
9 October 2014	141 mm/1 h, 401 mm/24 h	1000 m^3/s	Flash flood Bisagno and Fereggiano streams	300 million Euros; 250 people homeless	1 fatality

As previously mentioned, the Bisagno Valley is an important case study of a river basin in which artificial/anthropic intervention has become the dominant morphogenetic process since the 19th century, which has profoundly modified the hydrographic network. Among the many landforms created by human activities are, sensu [58]: (i) Made ground, (ii) worked ground, (iii) infilled ground, and (iv) landscaped ground. Examples of made grounds are landfills, sea embankments, and motorway and railway embankments [51]. Examples of worked grounds include open-air quarries on marly limestone, the often-uncontrolled excavation fronts of which have led to problems of slope stability. Examples of infilled grounds include moved material from road construction (digging upstream and filling on the valley side, with occasional quarries subsequently filled with carryovers). Finally, examples of landscaped ground characteristic to this region are the terraces supported by dry stone walls, whose origins could date back to the Middle Ages [59].

Terraces occupy almost 30% of the basin, and their construction has involved changes in the slopes and the more superficial stratigraphic horizons. Even the urban settled areas are landscaped ground. Indeed, construction of buildings involved earthmoving and modification of the hydrographic network through coverings and channels. Moreover, the insertion of weirs to limit bottom erosion and preserve the stability of the riverbanks inexorably narrowed the riverbeds [25,34].

2.2. Methods

The study was performed using data in GIS format published by the authorities of the Liguria Region. More precisely: (i) A 5 m DTM, (ii) the Ligurian Regional Landslides Database updated after the 2014 event, (iii) the Bisagno hydrographical network, and (iv) the digitized map of the historical evolution of building areas in the periods 1855, 1936, 1964, and 1986 (Figure 3a,b). Data of buildings erected from 1986 to 2006 were also used.

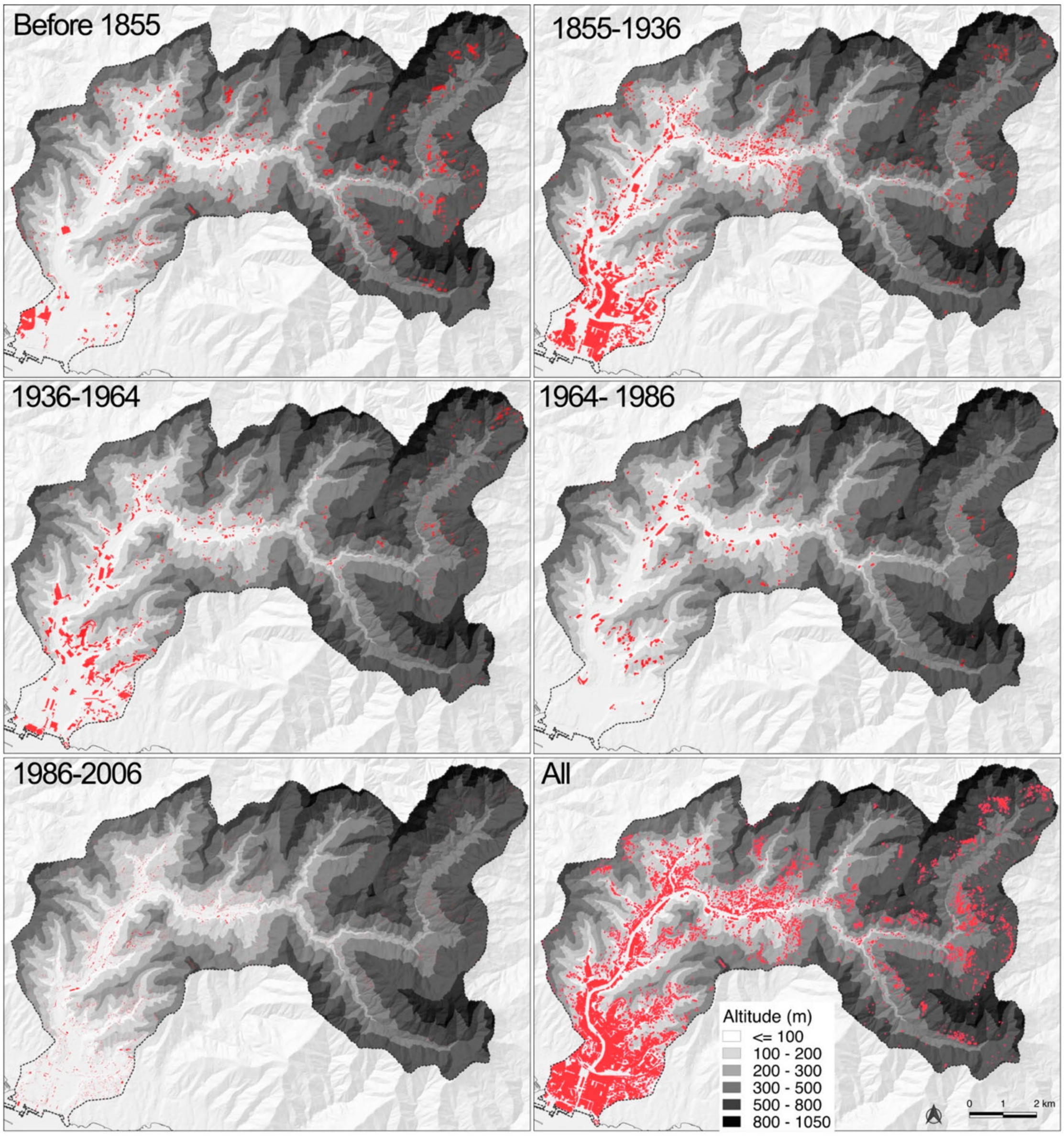
A morphometric analysis of urbanized surfaces was completed to show how these areas have changed over the study periods (building surfaces on altimetry, gradient classes, and aspect). Urbanized surface data per time period were calculated as a percentage of the respective class extension in the catchment area for every evaluated morphometric variable (altitude, gradient, and aspect class). Then, the same data were calculated as a percentage of the total urbanized areas for every evaluated time period. These two calculations substantiated what has been the urbanized saturation effect for every altitude, gradient, and aspect class.

It must be emphasized that the calculated values do not perfectly coincide with the real soil consumption in the considered time periods. This is due to: (1) The low detail of the map of historical evolution of built areas which did not include roads, and (2) the digitization process. The comparison with the actual soil consumption map [60] shows a difference in the order of 10%.

A spatial analysis was successively performed to assess the spatial relationships between the built surface, hydrographical network, floodplain, and landslides (DSGSDs included). The relationship between the built surface and the hydrographical network was performed through calculations with buffer areas of 10, 50, and 100 m of distance from the watercourses, whereas the spatial relationship between the built surface and the landslide/DSGSD was assessed through a simple intersection of layers. Furthermore, to highlight the effect of urbanization of the Bisagno floodplain, a buffer spatial analysis was performed on the 3.8 km final stretch from the stream's mouth. The analysis considered the present-day width of the channel.

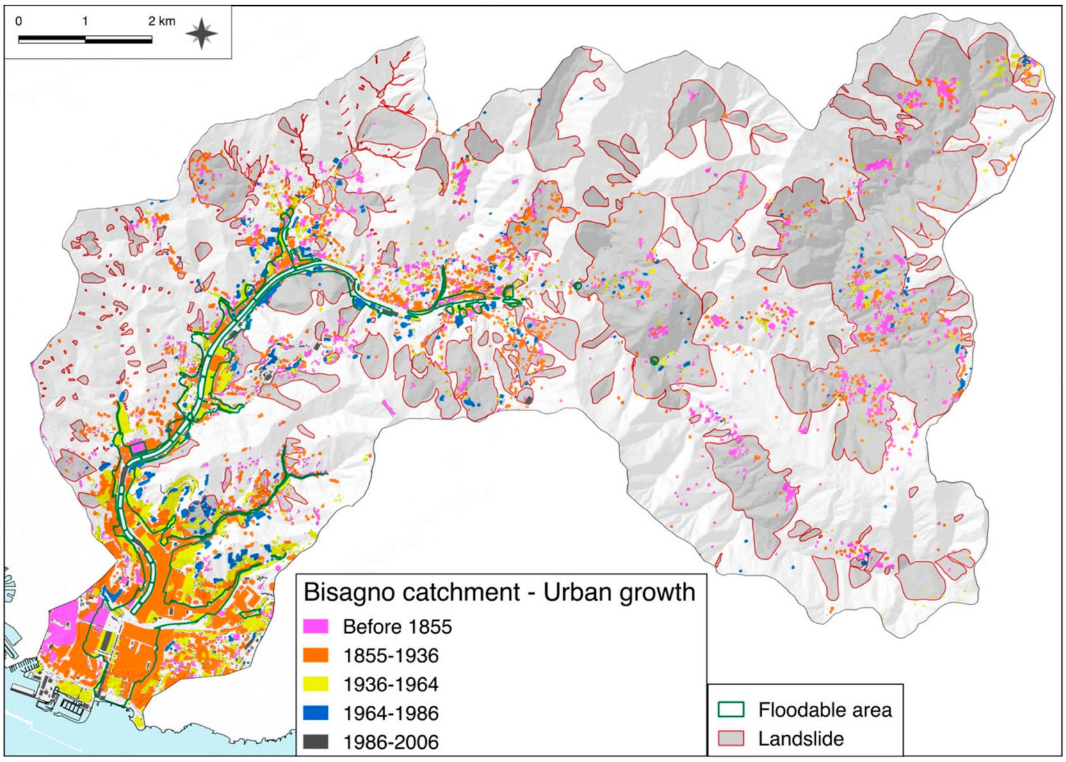
Regarding landslides/DSGSD, it must be pointed out that the calculation compares the present conditions of the built surface over past periods, and was performed to point out primarily the spatial relationships with large-scale complex landslides and Deep-Seated Gravitational Slope Deformations [3,61], which, as already mentioned, originated in a different morphoclimatic setting compared to the current one [62].

In the paper, the term *landslide* is used for all types of mass movements, including debris flows and soil slips [61,63], while the term *flood* is used for any events in which the floodwater would cover land that is normally dry (directive 2007/60/EC, 2007). The term *geo-hydrological hazards* is used to encompass landslide and flood hazards.



(**a**)

Figure 3. *Cont.*



(**b**)

Figure 3. (**a**) Evolution of urbanization (in red) in the Bisagno stream catchment over the examined time periods [64]. (**b**) Evolution of urbanization in the Bisagno basin over the examined time periods compared with areas exposed to floods and landslides/DSGSDs.

3. Results

3.1. Morphometry of Built Areas

Figure 3a,b shows the different degrees of building rates over different periods. The most important urban expansion occurred in the 1930s, while further significant construction occurred after the Second World War (until 1964).

The areas built before 1855 were largely scattered, with particular concentration in the upper catchment over the large-scale complex landslides/DSGSDs, while the most recent constructions essentially filled the empty spaces in the lower valley. The diagrams of the built surface per altimetry (Figure 4) show how the urban expansion is prevalent in low quotas (up to 100 m) through the entire examined period. Before 1855, construction also took place at higher altitudes (e.g., areas within the altitude classes of 400–500, 500–600, and 600–700 m) with a favorable S or SW aspect, both on paleo-landslides and DSGSDs.

This is more evident when examining the areas with gradients of up to 35% which were chosen for settlements until 1855; see, for example, the built surface per slope (Figure 5) and built surface per aspect (Figure 6).

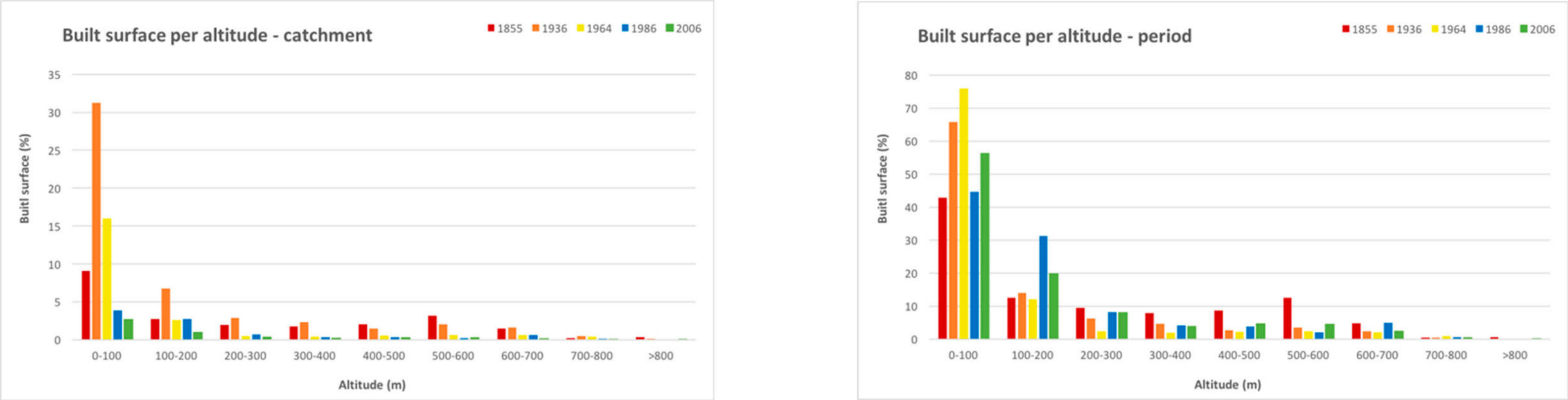


Figure 4. Built surface per altimetry: Across the catchment area (**left**) and over the studied time periods (**right**).

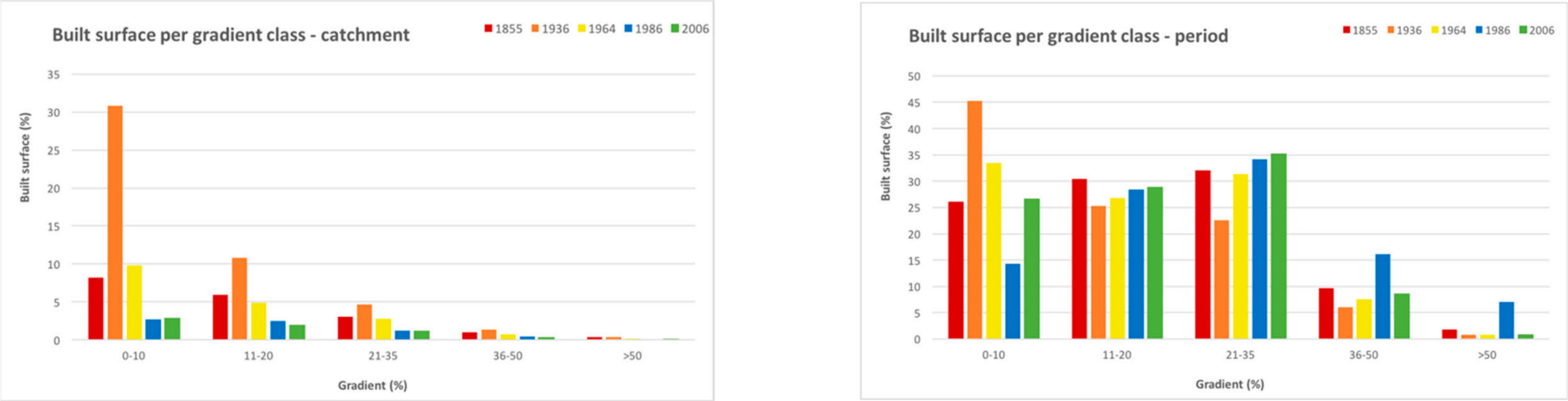


Figure 5. Built surface per gradient: Across the catchment area (**left**) and over the studied time periods (**right**).

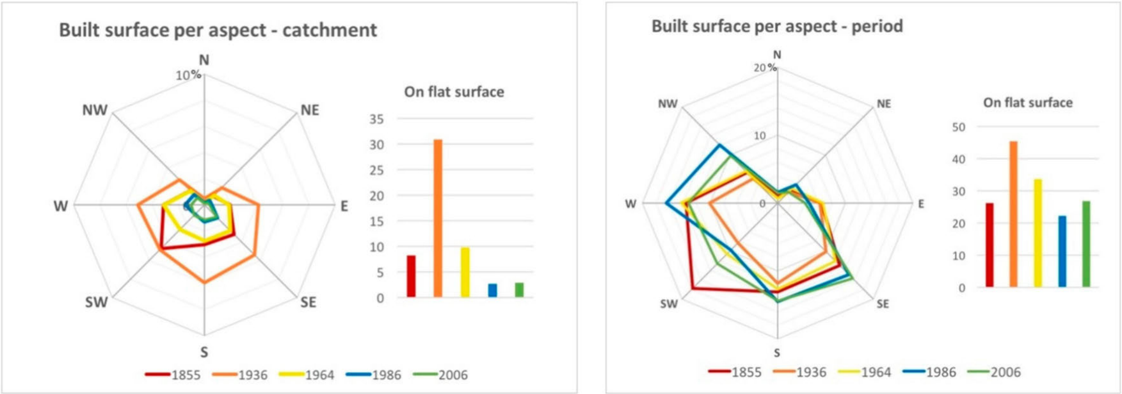


Figure 6. Built surface per aspect: Across the catchment area (**left**) and over the studied time periods (**right**).

During the period 1855–1936, urbanization was mainly concentrated in the floodplains, while in the period after World War II, construction expanded along higher-gradient slopes and even in aspect classes NW and NE (Figures 5 and 6). The calculations relative to both the class extension in the catchment area and the built environment over the study period confirm such trends. The built surface before 1855 is scattered both in altitude and gradient classes of up to 36–50%, and all aspect classes are almost equally populated. From 1855 to 1936, the large urban expansion concentrated in the floodplain areas, with the occupation of more than 30% of the total available area below the quota of 100 m. The gradient analysis shows that the gradient class that was built upon the most was 0–10%. Similarly, over the next period of time and up to 1964, constructions progressively saturated low altitude areas (Figure 4). This is particularly visible when looking at the value of the built surface during this specific stretch of time. It is worth emphasizing the relative importance of the class gradient of 21–35%. This trend appears to decrease for the next period up to 1986 and to accelerate again through 2006.

This urban growth was linked to the socio-economic trend before World War II, which favored industrialization at the expense of agriculture [29]. A similar impulse to abandon the hilly–mountainous hinterland and subsistence agricultural practices was also registered in the 1950s and 1960s during the post-war Italian 'economic boom' (Figure 3).

3.2. Urbanization and Hazard

The spatial relationships between the urban evolution and the geo-hydrological hazards are shown in Figures 7–9. The built surface was compared with the positions and states of activity of landslides, the buffering areas of the hydrographical network, and the buffering areas of the 3.8 km final stretch of the Bisagno stream (Figure 1). The analysis of the buffering area in the final stretch of the Bisagno channel shows that the channel width was dramatically reduced starting from the end of the 19th century. A recent study assessed a reduction from 120 to 50 m and from 280 to 70 m for a segment between two historical bridges [25].

The relationships of urbanization and landslides clearly show a sizeable presence of historical settlements over large-scale landslides and Deep-Seated Gravitational Slope Deformations (Figure 7); most likely, these areas were settled because of their reduced steepness, abundance of underground water, and the cultivability of their soil. The tendency to urbanize DSGSD sites was definitely lower in all of the subsequent studied periods. Nonetheless, in 1855, the built surface that was not on a landslide or on an area susceptible to landslide was the smallest of all the examined periods. It is worth noting that the chart of 1986 shows the highest value for built surface on active landslides and a small value on stable areas. This finding reveals a strong tendency to underestimate the high landslide hazard between 1964 and 1986, despite the various legislations that attempted to prevent building on high-hazard areas.

Figures 3 and 8 show the progressive nearing of constructions to the stream beds, with the latter displaying data in the 0–10, 10–50, and 50–100 m distance class areas for the whole hydrographical network. The highest value for construction in the 0–10 m class is in 1986, while the highest value for the 50–100 m class is in 1936 during the early urbanization of the Bisagno floodplain.

The effect of urbanization of the Bisagno floodplain was performed on the 3.8 km final stretch from the stream's mouth. The results displayed in Figure 9 show that in 1855, when the channel width was larger, no construction was erected within the distance classes 0–10 and 10–50 m. On the contrary, large areas (within these distance classes) were built in 1936 and even in the following periods, causing the urbanization of lower areas. The narrowing of the Bisagno channel was carried out just before 1936; thus, the effect is found in that studied time period. The left diagram of Figure 9 shows the percentage of the built surface versus the extension of the buffering areas; the 50% occupancy for the 10–50 and the 50–100 m distance classes clearly quantifies this large expansion. On the other hand, the saturation process proceeded even in the following periods, as shown in the right diagram of Figure 9; significant construction had been performed in 1964 and 2006.

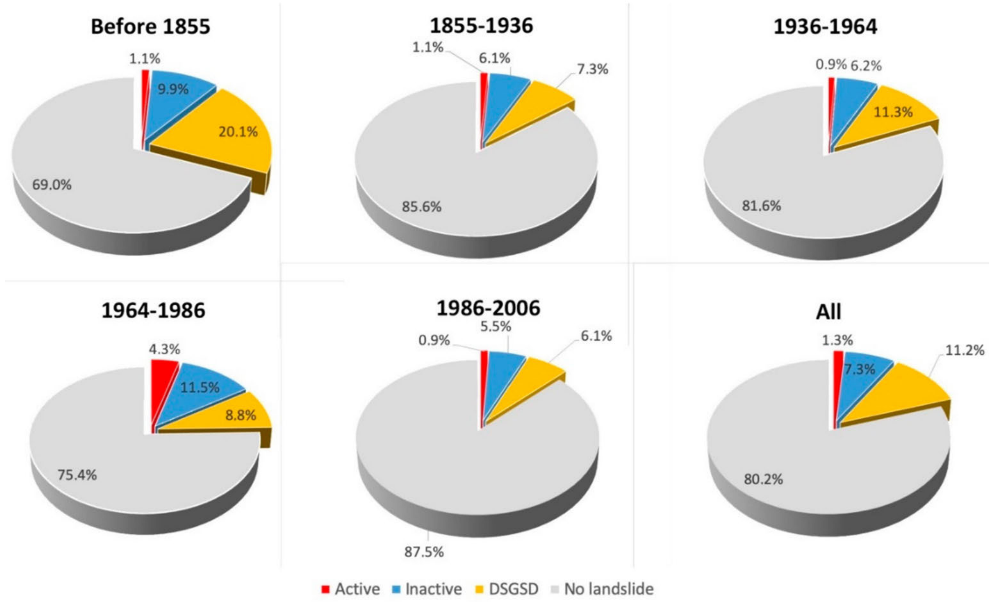


Figure 7. Built surface on landslide/DSGSD types over examined periods.

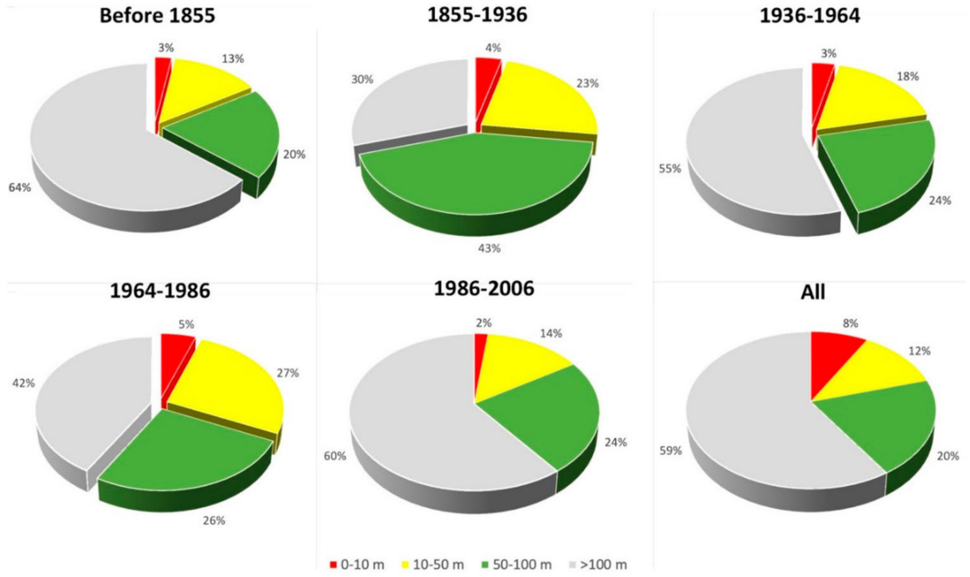


Figure 8. Built surface on watercourse buffering areas over the examined periods.

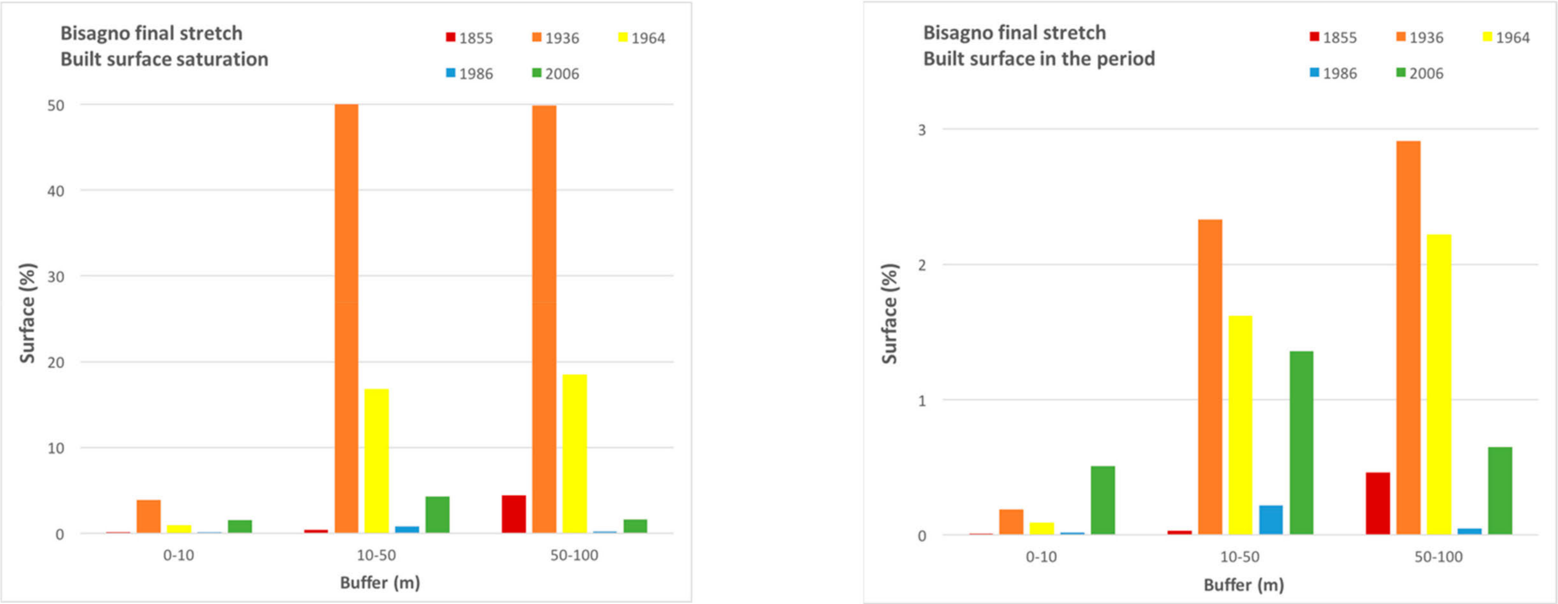


Figure 9. Built surface in the final 3.8 km of the Bisagno River versus buffer area (**left**) and over the studied time periods (**right**).

3.3. *Current Exposure to Geo-Hydrological Hazard*

Focusing the attention on the recent years, analysis of population census data, carried out in 1991, 2001, and 2011 (Istituto Nazionale di Statistica—National Statistics Institute) [65], was performed to assess population exposure to flood hazard. The intersection of these demographic data with the flood zones, with return periods of 50, 200, and 500 years, shows the progressive decrement of inhabitants in all three zones (Figure 10). This result is coherent with the population trend in the Municipality of Genoa, which decreased from about 800,000 inhabitants in the early 1970s to about 580,000 in 2011 [64]. The general reduction of the residing population translated into a lower population exposure to flood hazard in the period 1991–2011, yet it does not contribute to a better definition of risk levels across the area.

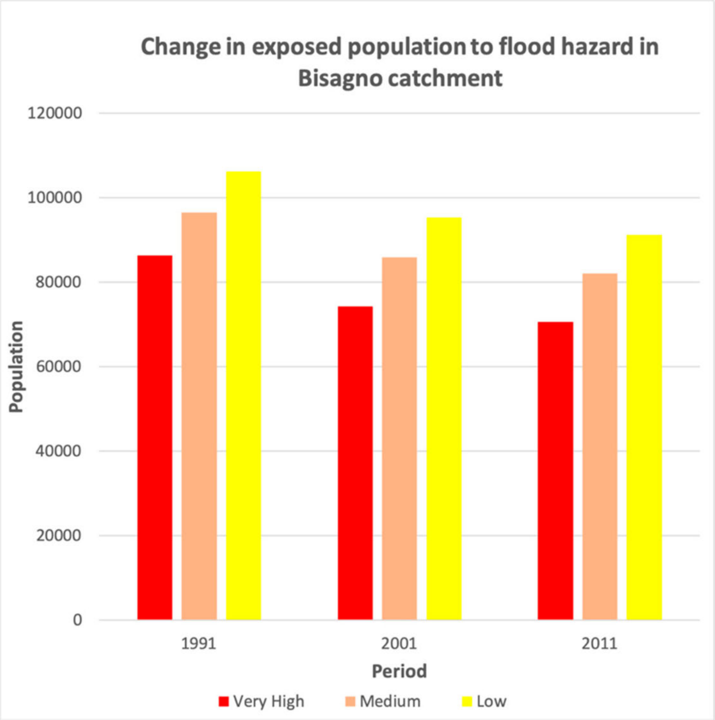


Figure 10. Population exposed to flood hazard in the flood-prone area with 50 (high), 200 (medium), and 500 year (low) return periods, computed for the years 1991, 2001, and 2011.

To provide a wider perspective on the actual level of exposure to flood and landslide hazards, an online database with all of the economic activities in the catchment was consulted. The addresses of the major economic activities, subdivided into eight typologies (see Figure 11), were extracted and geocoded in order to investigate their spatial relationships with the flood and landslide hazard zones. Figure 11 shows a high density of business activities in such hazardous zones, 492 of which are located in the floodable zones, while another 15 are located over landslides.

This result points out the high impact that floods and landslides have across the study area. Landslides appear to have greater effects on infrastructures than on business activities, which are mainly concentrated in the floodplain. A further critical element highlighted by this exposure analysis was that 25 schools appear to be located in floodable zones.

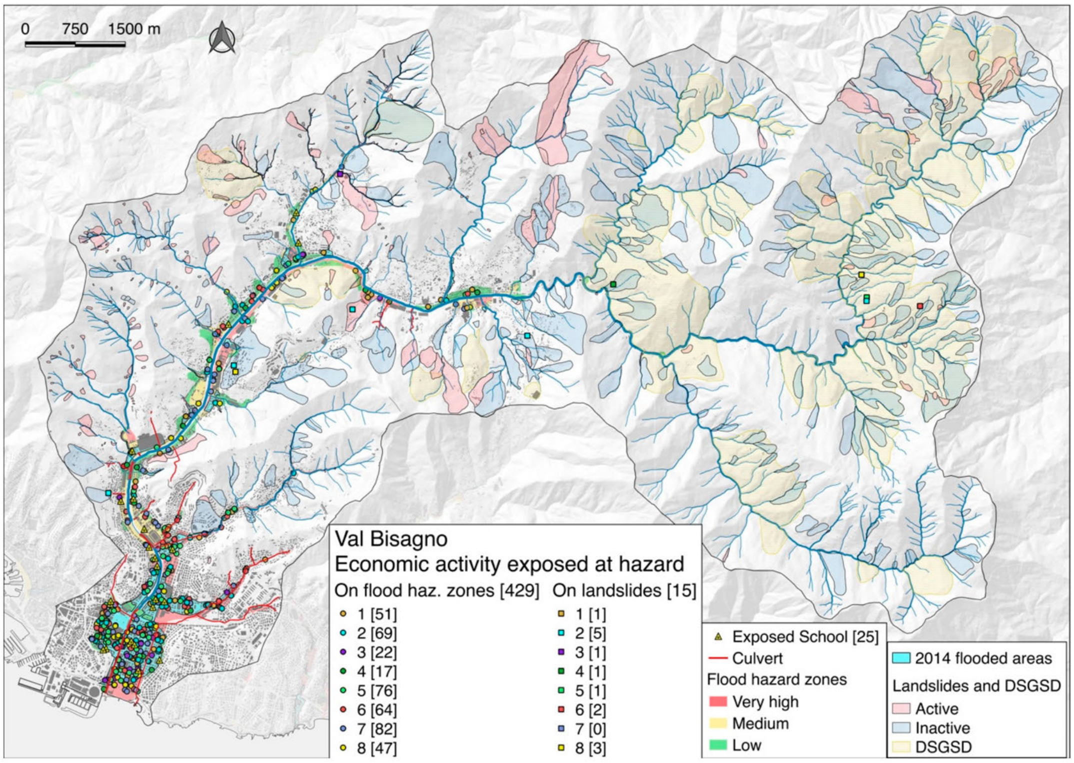


Figure 11. Main economic categories and number of affected businesses (in brackets) exposed to flood or landslide hazards in the Bisagno catchment area: 1) Clothing and food manufacture and wholesale, 2) pharmacy, medical analysis laboratory, hospice, drug production, and warehouse, 3) electronic, electro-mechanic, mechanic, and automation factory, 4) furniture production and wholesale, 5) bank, 6) shopping mall, 7) electrical components, hardware, restaurant, and hotel supply wholesale, 8) logistical and import/export warehouse, typography.

4. Discussion and Conclusions

Urbanization in the study area appears to have paralleled the socio-economic trend of progressively abandoning the hilly–mountainous hinterland while occupying the floodable areas during the expansion of the City of Genoa. This trend changed the pattern of exposure to landslide and flood hazards. Up to 1855, the few scattered settlements present in the Bisagno catchment area had been settled on complex landslides and Deep-Seated Gravitational Slope Deformations, some of which reactivated. Back then, the final stretch of the Bisagno Stream had not yet been narrowed and no constructions had been erected close to the wider channel.

After the urban expansion of the 1930s, exposure to floods and landslides grew sensibly, and the built surface progressively occupied the potentially floodable areas, pushing constructions closer and closer to the hydrographical network. An even higher exposure to landslides was caused by the recent expansion of built surface onto higher gradient slopes despite increasingly tightened legislations to reduce such exposure (Figure 9).

The exposure to geo-hydrological hazard was lower and limited to the relatively hazardous Deep-Seated Slope Gravitational Deformations and large-scale landslides until the early decades of the 20th century. The rapid urban growth between the World Wars and later periods dramatically increased flood risk [66], despite progress in science, technology, and improved regulations. It can be said that before the World Wars, the exposure to hazard was essentially avoided (or driven) by primary needs such as agricultural production, whereas in more modern times, an absolute faith in technological solutions, such as riverbanks and channel covering, lead geo-hydrological hazards to be systematically ignored or underrated, generating a dangerous sense of false safety. The consequent heightened exposure set the conditions for the dramatic disasters summarized in Table 2.

Land management policies in the studied area should consider the spatial and temporal trends of geo-hydrologic hazard exposure that were discussed above. As stated by Papadimitriu and Mariota [67], land planning is often disconnected from the spatial and temporal scales of the processes acting on the landscape. In particular, the time dimension is crucial; the optimum "7–32 year" time span [67] is disregarded in place of the current "less than 4 years" period, which is typically linked to the political election cycle. This discrepancy, which appears to have largely affected the study area, diminishes timely reaction to and planning for geo-hydrological risk reduction. Similarly, the choice of an appropriate spatial scale of analysis and intervention is crucial to devising effective land-use policies that can accommodate changes and mutual influences of different portions of the territory. Indeed, the catchment scale approach, considering the relationships between rural/mountainous areas and urban districts, is crucial for a proper risk management.

In terms of possible strategies, a mix of resistant and resilient solutions should be developed. Public education programs, as initially developed by the Municipality of Genoa after the dramatic events in 2011 and 2014, are pivotal to increasing awareness among residents of the high hazard and risk status of their locale [40,42,68]. Yet, structural solutions, such as the proposed bypass tunnel of the Bisagno stream [44–46], should be given serious consideration. Such a diversion channel would reduce the discharge to about 400 m^3/s in the final 4 km stretch, decreasing flood hazard in the densely urbanized floodplain (Figure 11). This structural solution, in spite of its being an expensive intervention, appears to be a sensible counteraction to the narrowing of the stream bed witnessed in recent decades. The bypass tunnel could potentially increase the overall discharge to 850 m^3/s (from the original 550 m^3/s). However, it should be noted that both discharge values have been exceeded during past flooding (Table 2).

Certainly, a comprehensive risk reduction plan for the entire Bisagno stream catchment area should be devised according to the overall geo-hydrological hazard conditions (i.e., considering the possible shallow landslides that could be triggered by short and heavy rainfalls). Mitigation and prevention activities should be thought out and implemented at the catchment-scale level. Decisions should be informed by continuous monitoring of known precursor phenomena. Such an overall land prevention and mitigation strategy should be implemented as soon as possible to prepare for the foreseen increase of extreme weather events in the coastal Mediterranean areas [69]. Because of these looming scenarios, it may be worth it to also explore alternative financial strategies like flood insurance programs [9], which, in already built-up areas, has been proven to be effective for financing various risk reduction activities.

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References

1. Canuti, P.; Casagli, N.; Pellegrini, M.; Tosatti, G. Chapter 28 'Geo-hydrological hazards'. In *Anatomy of an Orogen, the Apennines and Adjacent Mediterranean Basins*; Vai, G.B., Martini, I.P., Eds.; Kluwer Academic Publisher: Boston, MA, USA, 2001; pp. 513–532.
2. Brandolini, P.; Cevasco, A.; Firpo, M.; Robbiano, A.; Sacchini, A. Geo-hydrological risk management for civil protection purposes in the urban area of Genoa (Liguria, NW Italy). *Nat. Hazards Earth Syst. Sci.* **2012**, *12*, 943–959. [CrossRef]
3. Paliaga, G.; Luino, F.; Turconi, L.; Faccini, F. Inventory of geo-hydrological phenomena in Genoa Municipality (NW Italy). *J. Maps* **2018**, *15*, 28–37. [CrossRef]
4. Blahut, J.; Poretti, I.; De Amicis, M.; Sterlacchini, S. Database of geo-hydrological disasters for civil protection purposes. *Nat. Hazard* **2012**, *60*, 1065–1083. [CrossRef]

5. De Roo, A.; Barredo, J.; Lavalle, C.; Bodis, K.; Bonk, R. Potential Flood Hazard and Risk Mapping at Pan-European Scale. In *Digital Terrain Modelling, Lecture Notes in Geoinformation and Cartography*; Peckham, R.J., Jordan, G., Eds.; Springer: Berlin/Heidelberg, Germany, 2007; pp. 183–202.
6. Gaume, E.; Bain, V.; Bernardara, P.; Newinger, O.; Barbuc, M.; Bateman, A.; Viglione, A. A compilation of data on European flash floods. *J. Hydrol.* **2009**, *367*, 70–78. [CrossRef]
7. Ten Brinke, W.; Knoop, J.; Muilwijk, H.; Ligtvoet, W. Social disruption by flooding, a European perspective. *Int. J. Dis. Risk Red.* **2017**, *21*, 312–322. [CrossRef]
8. Diakakis, M.; Priskos, G.; Skordoulis, M. Public perception of flood risk in flash flood prone areas of Eastern Mediterranean: The case of Attica Region in Greece. *Int. J. Dis. Risk Red.* **2018**, *28*, 404–413. [CrossRef]
9. Roder, G.; Hudson, P.; Tarolli, P. Flood risk perceptions and the willingness to pay for flood insurance in the Veneto region of Italy. *Int. J. Dis. Risk Red.* **2019**, *37*, 101172. [CrossRef]
10. Jaedicke, C.; Van Den Eeckhaut, M.; Nadim, F.; Hervás, J.; Kalsnes, B.; Vidar Vangelsten, B.; Smith, J.T.; Tofani, V.; Ciurean, R.; Winter, M.G.; et al. Identification of landslide hazard and risk 'hotspots' in Europe. *Bull. Eng. Geol. Environ.* **2014**, *73*, 325–339. [CrossRef]
11. Scolobig, A.; Linnerooth-Bayer, J.; Pelling, M. Drivers of transformative change in the Italian landslide risk policy. *Int. J. Dis. Risk Red.* **2014**, *9*, 124–136. [CrossRef]
12. Lugeri, N.; Kundzewicz, Z.W.; Genovese, E.; Hochrainer, S.; Radziejewski, M. River flood risk and adaptation in Europe—Assessment of the present status. *Mitig. Adapt. Strateg. Glob. Chang.* **2010**, *15*, 621–639. [CrossRef]
13. Merz, B.; Aerts, J.; Arnbjerg-Nielsen, K.; Baldi, M.; Becker, A.; Bichet, A.; Blöschl, G.; Bouwer, L.M.; Brauer, A.; Cioffi, F.; et al. Floods and climate: Emerging perspectives for flood risk assessment and management. *Nat. Haz. Earth Syst. Sci.* **2014**, *14*, 1921–1942. [CrossRef]
14. Faivre, N.; Sgobbi, A.; Happaerts, S.; Raynal, J.; Schmidt, L. Translating the Sendai Framework into action: The EU approach to ecosystem-based disaster risk reduction. *Int. J. Dis. Risk Red.* **2018**, *32*, 4–10. [CrossRef]
15. Salvati, P.; Bianchi, C.; Rossi, M.; Guzzetti, F. Societal landslide and flood risk in Italy. *Nat. Hazards Earth Syst. Sci.* **2010**, *10*, 465–483. [CrossRef]
16. Avvisati, G.; Sessa, E.B.; Bellucci, E.; Colucci, O.; Marfè, B.; Marotta, E.; Nave, R.; Peluso, R.; Ricci, T.; Tomasone, M. Perception of risk for natural hazards in Campania Region (Southern Italy). *Int. J. Dis. Risk Red.* **2019**, *40*, 101164. [CrossRef]
17. Salvati, P.; Bianchi, C.; Fiorucci, F.; Giostrella, P.; Marchesini, I.; Guzzetti, F. Perception of flood and landslide risk in Italy: A preliminary analysis. *Nat. Hazards Earth Syst. Sci.* **2014**, *14*, 2589–2603. [CrossRef]
18. Salvati, P.; Pernice, U.; Bianchi, C.; Marchesini, I.; Fiorucci, F.; Guzzetti, F. Communication strategies to address geohydrological risks: The POLARIS web initiative in Italy. *Nat. Hazards Earth Syst. Sci.* **2016**, *16*, 1487–1497. [CrossRef]
19. Guzzetti, F.; Tonelli, G. Information system on hydrological and geomorphological catastrophes in Italy (SICI): A tool for managing landslide and flood hazards. *Nat. Hazards Earth Syst. Sc.* **2004**, *4*, 213–232. [CrossRef]
20. Guzzetti, F.; Stark, C.P.; Salvati, P. Evaluation of flood and landslide risk to the population of Italy. *Environ. Manag.* **2005**, *36*, 15–36. [CrossRef]
21. Barrera-Escoda, A.; Llasat, M.C. The role of climatic factors in evolving flood patterns in a Mediterranean region (1301–2012). *Hydrol. Earth Syst. Sci.* **2015**, *19*, 465–483. [CrossRef]
22. Latocha, A. Land-use changes and longer-term human–environment interactions in a mountain region (Sudetes Mountains, Poland). Natural versus human-induced effects. *Geomorphology* **2009**, *108*, 48–57. [CrossRef]
23. Agnoletti, M.; Emanueli, F.; Maggiari, G.; Preti, F. Landscape and hydrogeological risk. The environmental disaster of 25 October 2011 in Cinque Terre. In *Florence 2012, Studi e Ricerche/Essays and Researches*; Agnoletti, M., Carandini, A., Santagata, W., Eds.; Bandecchi and Vivaldi: Pontedera, Pisa, Italy, 2012; pp. 25–46.
24. Boudou, M.; Danière, B.; Lang, M. Assessing changes in urban flood vulnerability through mapping land use from historical information. *Hydrol. Earth Syst. Sci.* **2016**, *20*, 161–173. [CrossRef]
25. Faccini, F.; Paliaga, G.; Piana, P.; Sacchini, A.; Watkins, C. The Bisagno stream catchment (Genoa, Italy) and its major floods: Geomorphic and land use variations in the last three centuries. *Geomorphology* **2016**, *273*, 14–27. [CrossRef]

26. Marchi, L.; Cavalli, M.; Amponsah, W.; Borga, M.; Crema, S. Upper limits of flash flood stream power in Europe. *Geomorphology* **2016**, *272*, 68–77. [CrossRef]
27. Camarasa-Belmonte, A.M.; Soriano-Garcia, J. Flood risk assessment and mapping in peri-urban Mediterranean environments using hydrogeomorphology. Application to ephemeral streams in the Valencia region (eastern Spain). *Landsc. Urban Plan.* **2012**, *104*, 189–200. [CrossRef]
28. Faccini, F.; Luino, F.; Sacchini, A.; Turconi, L. Flash flood events and urban development in Genoa (Italy): Lost in translation. In *Engineering Geology for Society and Territory*; Lollino, G., Manconi, A., Guzzetti, F., Culshaw, M., Bobrowsky, P., Luino, F., Eds.; Springer International Publishing: Cham, Switzerland, 2015; pp. 797–801.
29. Agnoletti, M. Valorizing the European rural landscape: The Italian national register of historical rural landscapes. In Proceedings of the International Conference on the European Landscape Convention in Research Perspective, Florence, Italy, 18–19 October 2010.
30. Rogger, M.; Agnoletti, M.; Alaoui, A.; Bathurst, J.C.; Bodner, G.; Borga, M.; Chaplot, V.; Gallart, F.; Glatzel, G.; Hall, J.; et al. Land use change impacts on floods at the catchment scale: Challenges and opportunities for future research. *Water Resour. Res.* **2017**, *53*, 5209–5219. [CrossRef]
31. Agnoletti, M.; Errico, A.; Santoro, A.; Dani, A.; Preti, F. Terraced landscapes and hydrogeological risk. Effects of land abandonment in Cinque Terre (Italy) during severe rainfall events. *Sustainability* **2019**, *11*, 235. [CrossRef]
32. Trigo, I.F.; Davies, T.D.; Bigg, G.R. Objective climatology of cyclones in the Mediterranean region. *J. Clim.* **1999**, *12*, 1685–1696. [CrossRef]
33. Agenzia Regionale Per La Protezione Dell'ambiente Liguria (ARPAL). Atlante Climatico Della Liguria [Ligurian Climate Atlas]. 2013. Available online: https://www.arpal.gov.it/contenuti_statici//clima/atlante/Atlante_climatico_della_Liguria.pdf (accessed on 4 February 2020).
34. Luino, F.; Paliaga, G.; Roccati, A.; Sacchini, A.; Turconi, A.; Faccini, F. Anthropogenic changes in the alluvial plains of the Tyrrhenian Ligurian basins. *Rend. Online Soc. Geol. Ital.* **2019**, *48*, 10–16. [CrossRef]
35. Hally, A.; Caumont, O.; Garrote, L.; Richard, E.; Weerts, A.; Delogu, F.; Fiori, E.; Rebora, N.; Parodi, A.; Mihalović, A.; et al. Hydrometeorological multi-model ensemble simulations of the 4 November 2011 flash flood event in Genoa, Italy, in the framework of the DRIHM project. *Nat. Hazards Earth Syst. Sci.* **2015**, *15*, 537–555. [CrossRef]
36. Acquaotta, F.; Faccini, F.; Fratianni, S.; Paliaga, G.; Sacchini, A.; Vilìmek, V. Increased flash flooding in Genoa Metropolitan Area: A combination of climate changes and soil consumption? *Meteorol. Atmos. Phys.* **2019**, *131*, 1099–1110. [CrossRef]
37. Basoni, A.; Pepe, M.; Brivio, A.; Mancini, M. Effect of seasonal land use cover from satellite data on surface runoff in two Mediterranean catchments. In Proceedings of the SPIE 4171. Remote Sensing for Agriculture, Ecosystems, and Hydrology II, Barcelona, Spain, 23 January 2001.
38. Rosso, R.; Rulli, M.C. An integrated simulation method for flash-flood risk assessment: 2. Effects of changes in land-use under a historical perspective. *Hydrol. Earth Syst. Sci.* **2002**, *6*, 285–294. [CrossRef]
39. Rulli, M.C.; Rosso, R. An integrated simulation method for flash-flood risk assessment: 1. Frequency predictions in the Bisagno River by combining stochastic and deterministic methods. *Hydrol. Earth Syst. Sci.* **2002**, *6*, 267–284. [CrossRef]
40. Silvestro, F.; Gabellani, S.; Giannoni, F.; Parodi, A.; Rebora, N.; Rudari, R.; Siccardi, F. A hydrological analysis of the 4 November 2011 event in Genoa. *Nat. Hazards Earth Syst. Sc.* **2012**, *12*, 2743–2752. [CrossRef]
41. Faccini, F.; Luino, F.; Paliaga, G.; Sacchini, A.; Turconi, L. Yet another disaster flood of the Bisagno stream in Genoa (Liguria, Italy): October the 9th–10th 2014 event. *Rend. Online Soc. Geol. Ital.* **2015**, *35*, 128–131. [CrossRef]
42. Silvestro, F.; Rebora, N.; Giannoni, F.; Cavallo, A.; Ferraris, L. The flash flood of the Bisagno Creek on 9th October 2014: An "unfortunate" combination of spatial and temporal scales. *J. Hydrol.* **2016**, *541*, 50–62. [CrossRef]
43. Faccini, F.; Luino, F.; Paliaga, G.; Sacchini, A.; Turconi, L.; de Jong, C. Role of rainfall intensity and urban sprawl in the 2014 flash flood in Genoa City, Bisagno catchment (Liguria, Italy). *Appl. Geogr.* **2018**, *98*, 224–241. [CrossRef]

44. Ferrari, M.; Belicchi, M.; Cerlini, D.; Majone, U. The Bisagno River Diversion. In Proceedings of the International Conference on Fluvial Hydraulics, RIVER FLOW 2014, Lausanne, Switzerland, 3–5 September 2014; pp. 1757–1765.
45. Lunardi, G.; Cassani, G.; Gatti, M.; Spigarelli, B.; Zenti, C.L. Resilient city: The case of Bisagno diversion tunnel. In *Tunnels and Underground Cities: Engineering and Innovation Meet Archaeology, Architecture and Art*; Peila, D., Viggiani, G., Celestino, T., Eds.; CRC Press: Boca Raton, FL, USA; London, UK; New York, NY, USA, 2019; pp. 5159–5169.
46. Redaelli, P.; Bringiotti, M. The Fereggiano River diversion in Genoa. Tunnels and Undergorund Cities: Engineering and Innovation Meet Archaeology, Architecture and Art. In Proceedings of the WTC 2019 ITA-AITES World Tunnel Congress, Naples, Italy, 3–9 May 2019; pp. 6110–6119.
47. Cevasco, A.; Sacchini, A.; Robbiano, A.; Vincenzi, E. Evaluation of Rainfall Thresholds for triggering shallow landslides on the Genoa Municipality area (Italy): The case study of the Bisagno Valley. *Ital. J. Eng. Geol. Environ.* **2010**, *1*, 35–50.
48. Paliaga, G.; Faccini, F.; Luino, F.; Turconi, L.; Bobrowsky, P. Geomorphic processes and risk related to a large landslide dam in a highly urbanized Mediterranean catchment (Genova, Italy). *Geomorphology* **2019**, *327*, 48–61. [CrossRef]
49. Paliaga, G.; Faccini, F.; Luino, F.; Turconi, L. A spatial multicriteria prioritizing approach for geo-hydrological risk mitigation planning in small and densely urbanized Mediterranean basins. *Nat. Hazards Earth Syst. Sci.* **2019**, *19*, 53–69. [CrossRef]
50. Sorg, L.; Medina, N.; Feldmeyer, D.; Sanchez, A.; Vojinovic, Z.; Birkmann, J.; Marchese, A. Capturing the multifaceted phenomena of socioeconomic vulnerability. *Nat. Hazards* **2018**, *92*, 257–282. [CrossRef]
51. Piana, P.; Faccini, F.; Luino, F.; Paliaga, G.; Sacchini, A.; Watkins, C. Geomorphological Landscape Research and Flood Management in a Heavily Modified Tyrrhenian Catchment. *Sustainability* **2019**, *11*, 4594. [CrossRef]
52. Fuchs, S.; Keiler, M.; Zischg, A.; Brundl, M. The long-term development of avalanche risk in settlements considering the temporal variability of damage potential. *Nat. Haz. Earth Sys. Sci.* **2005**, *5*, 893–901. [CrossRef]
53. Keiler, M.; Sailer, R.; Jorg, P.; Weber, C.; Fuchs, S.; Zischg, A.; Sauermoser, S. Avalanche risk assessment—A multi-temporal approach, results from Galtur, Austria. *Nat. Haz. Earth Sys. Sci.* **2006**, *6*, 637–651. [CrossRef]
54. Brancucci, G.; Paliaga, G. Geomorphic characterization of the main drainage basins of maritime Liguria (Italy)—Preliminary results. *Geogr. Fis. Din. Quat.* **2005**, *7*, 59–67.
55. Brandolini, P.; Faccini, F.; Paliaga, G.; Piana, P. Man-Made landforms survey and mapping of an urban historical centre in a coastal Mediterranean environment. *Geogr. Fis. Din. Quat.* **2018**, *41*, 97–102.
56. Sassa, K. The geotechnical classification of landslides. In Proceedings of the IVth International Conference and Workshop on Landslides, Tokyo, Japan, 23–31 August 1985; pp. 31–40.
57. Autorità di Bacino Regionale. Piano di Bacino Stralcio per l'assetto Idrogeologico del Torrente Bisagno [Basin Master Plan for the Geo-Hydrological Arrangement]. 2017. Available online: http://www.pianidibacino.ambienteinliguria.it/GE/bisagno/bisagno.html (accessed on 4 February 2020).
58. Rosenbaum, M.S.; McMillan, A.A.; Powel, J.H.; Cooper, A.H.; Culshaw, M.G.; Northmore, K.J. Classification of artificial (man-made) ground. *Eng. Geol.* **2003**, *69*, 399–409. [CrossRef]
59. Paliaga, G.; Giostrella, P.; Faccini, F. Terraced landscape as cultural and environmental heritage at risk: An example from Portofino Park (Italy). *Ann. Ser. Hist. Sociol.* **2016**, *26*, 513–522.
60. Istituto Superiore per la Ricerca e la Protezione Ambientale (ISPRA). Consumo di Suolo, Dinamiche Territoriali e Servizi Ecosistemici [Soil Consumption, Spatial Dynamics and Ecosystem Services]. 2019. Available online: http://www.isprambiente.gov.it/it/temi/suolo-e-territorio/il-consumo-di-suolo/i-dati-sul-consumo-di-suolo (accessed on 4 February 2020).
61. Hungr, O.; Leroueil, S.; Picarelli, L. The Varnes classification of landslide types, an update. *Landslides* **2014**, *11*, 167–194. [CrossRef]
62. Sacchini, A.; Faccini, F.; Ferraris, F.; Firpo, M.; Angelini, S. Large-scale landslide and Deep-Seated Gravitational Slope Deformation of the Upper Scrivia Valley (Northern Apennine, Italy). *J. Maps* **2016**, *12*, 344–358. [CrossRef]
63. UNESCO Working Party on World Landslide Inventory. A suggested method for describing the activity of a landslide. *Bull. Int. Ass. Eng. Geol.* **1993**, *47*, 53–57. [CrossRef]

64. Regione Liguria. Map of Historical Evolution of Urbanization at Scale 1:50.000 (in Italian). 1986. Available online: https://geoportal.regione.liguria.it/catalogo/mappe.html (accessed on 4 February 2020).
65. Istituto Nazionale di Statistica (ISTAT). Censimento Permanente Della Popolazione, 1991, 2001 2011 [Permanent Population Census]. Available online: https://www.istat.it/ (accessed on 4 February 2020).
66. Roccati, A.; Luino, F.; Turconi, L.; Piana, P.; Watkins, C.; Faccini, F. Historical geomorphological research of a Ligurian coastal floodplain (Italy) and its value for management of flood risk and environmental sustainability. *Sustainability* **2018**, *10*, 3727. [CrossRef]
67. Papadimitriou, F.; Mairota, P. Spatial Scale-Dependent Policy Planning for Land Management in Southern Europe. In *Global to Local: Ecological Land Classification*; Springer: Dordrecht, The Netherlands, 1996; pp. 47–57.
68. Scolobig, A.; Prior, T.; Schröter, D.; Jörin, J.; Patt, A. Towards people-centred approaches for effective disaster risk management: Balancing rhetoric with reality. *Int. J. Dis. Risk Red.* **2015**, *12*, 202–212. [CrossRef]
69. Hertig, E.; Seubert, S.; Paxian, A.; Vogt, G.; Paeth, H.; Jacobeit, J. Changes of total versus extreme precipitation and dry periods until the end of the twenty-first century: Statistical assessments for the Mediterranean area. *Theor. Appl. Climatol.* **2013**, *111*, 1–20. [CrossRef]