multi-Risk sciEnce for resilienT commUnities undeR a changiNgclimate

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ABSTRACT

The Deliverable examines three Unit of Territorial Elaboration (UTE) – Genoa, Naples and Friuli Venezia Giulia (FVG)– selected as representative case studies of the complexity and diversity of Italian urban areas exposed to natural hazards. For each city, the study reconstructs the main physical and settlement characteristics, highlighting the influence of geomorphological and coastal factors on patterns of development, land use and densification. Socio-demographic and economic trends show heterogeneous trajectories: selective growth and pronounced ageing in the North, population decline and structural economic fragility in the South, and increasing polarisation between consolidated urban cores and marginal districts. Cultural and productive assets, while essential components of local identity and competitiveness, also contribute to exposure when located in highly vulnerable zones.

Risk scenarios integrate historical data on major natural events recorded over the past thirty years, primarily extreme precipitation, floods, landslides and storm surges. The three urban areas share an intensification of high-impact events, with significant economic losses and damage to buildings, transport networks and essential services, along with disproportionate social consequences for vulnerable population groups. In Naples, the territorial risk profile is further shaped by volcanic hazards and bradyseism, which interact with high settlement density and complex territorial dynamics, amplifying exposure and the need for continuous monitoring and emergency preparedness.

Overall, the Assessment Report provides a comparative understanding of how vulnerability, exposure and response capacity differently shape urban resilience in the three cities, and offers essential evidence for designing more targeted and territorially sensitive disaster-risk-reduction policies.

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4.1 The Context of the UTE GENOA

4.1.1 The Territory

Genoa is a polycentric, densely populated and socially heterogeneous city characterised by a complex and highly stratified urban structure. The settlement layout resembles that of a coastal metropolitan corridor compressed between the shoreline to the south and an articulated system of hills and mountains to the north, marked by steep and often unstable slopes. The municipality covers approximately 240 km² and hosts around 550,000 residents (2023), making it the sixth largest city in Italy by population. With a density close to 2,290 inhabitants per km², the urban fabric is compact, continuous and strongly interlocked with the physical configuration of the terrain.

The city's geomorphological setting has historically directed urban development both longitudinally, following the coast, and vertically, through neighbourhoods distributed in altimetric succession up to around 300 metres. This has produced a highly layered metropolitan space, where residential areas, critical infrastructures and productive facilities coexist in close proximity across different elevation gradients. Terraces, embankments, tunnels and viaducts testify to the continuous adaptation of the built environment to a steep and geologically complex landscape.

The natural dimension of the territory remains a defining element of Genoa's identity and urban metabolism. The coastal front alternates between sandy and pebble shorelines, artificial embankments and harbour developments, shaped by strong marine dynamics including storm surges and wave actions that interact with a densely urbanised waterfront. Inland, the relief system is characterised by narrow valleys, ridges and slopes prone to erosion and shallow landslides, with soils and lithologies that respond rapidly to intense rainfall.

The hydrographic network plays a central role in structuring both the physical territory and urban dynamics. Dozens of minor watercourses flow across the city, feeding into the two major river basins — the Polcevera to the west and the Bisagno to the east — which cut the urban fabric perpendicularly to the coastline. These river systems function as natural longitudinal and transverse axes, influencing settlement expansion, infrastructure siting, ecological connectivity and environmental risks. Many stretches have been partially channelled or covered, integrating watercourses into the urban continuum while simultaneously reducing natural floodplain space.

Overall, Genoa's territorial structure results from the continuous interplay between anthropic pressures and geomorphological processes. The city's growth has been shaped — and constrained — by its natural setting, generating a highly distinctive metropolitan morphology where coastal, fluvial and mountainous environments converge in a limited space, producing both exceptional landscape value and an intrinsically complex spatial organisation.

4.2.1 The socio-economic and demographic context

The analysis of Genoa's socio-economic and demographic profile was conducted by analysing data from the last two censuses (2011-2021) compiled by ISTAT and organised in the survey on the state of security and degradation of Italian metropolitan cities and their suburbs.

Consultation of this survey, which was carried out in 2017 with data from 2011 and repeated in 2024 with data from 2021, provided a cluster of relevant indicators with stock data (referring to one year) and flow data (to identify trends).

The RETURN working group focused on 13 indicators relating to three factors: demography, social structure, and economic and housing conditions (Tab.1). These indicators offer a necessarily partial snapshot of the processes that create the conditions for social exposure and vulnerability to natural hazards. The partiality is due both to the phenomena described by the indicators and to the availability of data, the two criteria that guided the selection. However, in our opinion, they offer a good introduction to the socio-spatial context of Genoa, which is highly heterogeneous internally (see paragraph 1.3).

Table 1: Socio-economic and demographic indicators selected for the framework

Demographics	Socio-economic condition
Total population	Young people aged 18-25 who are not in education or employment
Population aged 0-14	Adults with diploma/degree
Ageing index	Index of non-completion of secondary school
Incidence of young people up to 24 years of age	Unemployment rate
Foreign residents	Incidence of households with potential hardship
Incidence of foreigners	Average property value

Overall (see Tab. 2), the data for the Municipality of Genoa show a picture of continuity in long-term structural trends: demographic decline, ageing population, growth in the foreign component and overall stability of economic and housing indicators. However, some flows show significant elements of discontinuity, particularly in terms of generational balance, education and the condition of young people.

Table 2: Socio-economic and demographic trends in Genoa (2011 - 2021)

Indicator	2011	2021	Observations
Resident population	586,180	561,203	Decrease of approximately 25,000 (-4.3%) continuing demographic

			decline.
Population aged 0-14	67,250	60,958	Decrease of 9.3%, impoverishment of the youth base.
Foreign residents	44,379	57,840	+30% Significant growth in the migrant component.
Ageing index	241.2	264.7	+23 points significant demographic ageing.
Incidence of foreigners	75.7	103.1	significant growth (+36%).
Young people not in employment, education or training (NEET)	8.1	17.7	More than doubled marked increase in youth vulnerability.
Percentage of adults with a diploma or degree	65.1	73	significant improvement (+8 points).
Average property value	€2,047/m²	€1,750/m²	Decrease of approximately -14.5%.
Unemployment rate	7.9	7.9	Stable but with differences between neighbourhoods
Incidence of households in economic hardship	1.3	1.3	Stable figure but with differences within neighbourhoods

In particular, the following phenomena emerge as relevant for the purposes of an analysis aimed at identifying the actors and interests involved in natural risk management, as modified by climate change.

Declining population and increasing ageing

The resident population fell from 586,180 to 561,203 inhabitants, confirming a loss of over 25,000 (-4.3%) and consolidating the downward trend that has characterised Genoa for several decades. The decline in the 0-14 age group (from 67,250 to 60,958, -9.3%) accentuates the rarefaction of the younger cohorts and foreshadows a progressive weakening of the demographic base, with potential repercussions on the school system, workforce turnover and local economic vitality. At the same time, the old-age index rose from 241.2 to 264.7, indicating that for every 100 young people there are now over 260 elderly people. This figure places Genoa among the oldest urban areas in Europe and testifies to the difficulty of the area in attracting and retaining young people. The incidence of elderly people living alone is growing (32.1% in 2017) and in 2024 almost 9% of the population over 67 will be living alone without owning their own home, highlighting a risk of isolation and housing insecurity in old age.

Growth in foreign nationals and inequalities

In stark contrast to the overall decline in population, the number of foreign residents has risen from 44,379 to 57,840 (+30%), leading to an increase in their incidence on the total number of residents (from 75.7 to 103.1 per thousand). The immigrant population is therefore the only segment that is expanding and contributes, albeit partially, to limiting the overall decline. However, the increased presence of foreign nationals is accompanied by complex social indicators: high rates of early school leaving, especially among foreign students (42.9%), highlight significant inequalities in educational integration. This educational gap risks translating into long-term marginalisation, with repercussions on the labour market and social cohesion.

Growth in human capital

Despite the critical issues, the overall level of schooling shows an improvement: the proportion of adults with a diploma or degree has grown from 65.1% to 73%, a sign of a gradual increase in human capital. At the same time, the rate of non-completion of the first cycle has decreased (from 3.4% to 2.6%), suggesting greater compliance with compulsory schooling. However, the increase in the number of 18-24 year olds who left the system early (13.8%) and the very high dropout rate among foreigners indicate that the improvement mainly concerns the adult generations, while the new cohorts encounter greater difficulties in remaining in education.

NEETs double and the number of elderly people living alone increases

A particularly uneven figure concerns the incidence of young people up to the age of 24 who are not in employment, education or training (NEET), which has doubled from 8.1% to 17.7%. This phenomenon, combined with the stagnation of the unemployment rate at 7.9%, indicates that a growing proportion of the young population remains on the margins of both the productive and educational systems.

Falling property values and decline in home ownership

The average property value fell from €2,047 to €1,750 per square metre (-14.5%), in line with the trend towards devaluation of building stock in mature centres and the decline in residential demand. At the same time, the percentage of households not living in owner-occupied housing increased (30.1%), a sign of a transformation in housing patterns and a growing dependence on the rental market. Despite this, indicators of housing hardship (rate of substandard housing, overcrowding index) remain very low, confirming a generally good quality of housing and adequate building stock.

Stable employment

On the economic front, the situation appears to be essentially stable: the employment rate is growing, but the unemployment rate remains unchanged at 7.9%, a figure which, although not high, should be viewed in the light of the demographic composition – a largely elderly and therefore less active population. The maintenance of a constant level of households with potential economic hardship (1.3%) indicates that social difficulties have not worsened across the board, but have probably polarised around specific groups (young people, foreigners, elderly people living alone). The incidence of precarious workers in the 35–64 age group (1.4%) confirms the relative stability of the 'mature' labour market, but at the same time highlights the generational gap with regard to new forms of precariousness.

4.1.3 Seven cities in one: trends in the districts

Data referring to the entire municipal territory only allow partial access to understanding the socio-economic and demographic characteristics of the city. Genoa is, in fact, a city with significant socio-spatial stratification.

In this paragraph, we illustrate: i) a proposal to divide the city into socio-spatial macro-areas that only partially coincide with the administrative boundaries of the municipalities; ii) we focus on the most 'pressing' indicators, i.e. those with the highest peaks, and observe how they affect the various neighbourhoods; iii) we look at the flow data for the last ten years to observe variations within the seven macro-zones.

The availability of data on the 13 indicators at neighbourhood level (Istat identifies 71 municipal sub-areas for the census) allows us to identify seven macro-areas in the city, which are united by their geographical proximity and by sharing most of their socio-economic and demographic values. For example, we decided to associate Sestri Ponente with the rest of Ponente, even though it is geographically closer to Cornigliano and Sampierdarena, because its socio-economic and demographic indicators are more similar to those of Voltri or Pegli. The same applies to neighbourhoods such as Lagaccio and Castelletto: in terms of 'territorial proximity', they belong to the historic centre, but their social characteristics (and urban history) place them in two different macro-areas: Lagaccio in the central hills (which also includes Bolzaneto), Castelletto in the residential centre, with Foce and Brignole.

Like any categorisation, this one is necessarily generic and contains contradictions and inconsistencies, but it allows for a less generic picture than the traditional one that divides the city in two (Ponente and Levante) and lays the foundations for a greater understanding of how natural risk interacts in these different territories.

- Ponente (from Crevari to Sestri, 1-9): retains a strong and popular identity, anchored to the sea and a dense but stable urban fabric. Here, the population is on average elderly, with an old-age index above the municipal average and a slow but steady decline in residents. However, compared to the 'Medio Ponente', the area maintains good social cohesion and lower levels of vulnerability: few families in economic hardship, low unemployment rates, stable property values around €2,000/m². It is the 'Genoa that resists', where the quality of life and local networks mitigate demographic decline.
- Medio Ponente (from Cornigliano to Sampierdarena, 10 - 13; 22 -26) is the part of the city that has paid the highest price for deindustrialisation. Economic and social indicators paint a complex picture: high unemployment, a significant incidence of vulnerable families, property values below €1,500/m². The foreign population is growing rapidly, a sign of social replacement that keeps the area alive but profoundly transforms its composition. It is a Genoa in transition, seeking a new balance between working-class memory and new urban marginality.
- Valpolcevera and the central hills (Oregina, Lagaccio, Certosa, Rivarolo, Begato, Bolzaneto, 14-21; 27-32) — constitute an extension of the post-industrial west, with further socio-spatial and economic emergencies affecting the more peripheral neighbourhoods. The data show sharp demographic declines (Lagaccio has lost 20% of its population in ten years, as have Bolzaneto and Oregina), high unemployment rates and low education levels throughout the area. The most significant difference with the post-industrial west, particularly when considering the higher neighbourhoods of Valpolcevera, is in terms of accessibility to infrastructure, the lack of a neighbourhood identity (and therefore social capital), and the significantly less valuable housing stock. It is perhaps the least visible and most neglected part of Genoa.
- The old town centre (Pré, Maddalena, Molo) has characteristics that are unique in the city. From a demographic point of view, it is a growing area: in ten years, the population has increased by 10% (approximately +2,500 people). It is the youngest and most cosmopolitan neighbourhood, with some areas where foreigners exceed 30% of the total population, and it is also the most touristy neighbourhood, where most events and initiatives are concentrated. Property values is growing unevenly: in Molo, it has increased by 25%, which is almost unique in the city, while it has decreased (and not by a small amount) in Pré, a sign of a clear distinction between the historic 'districts' of the centre. The historic centre is a neighbourhood with urgent socio-economic and housing issues, condensing contradictions present throughout the city, sometimes within a single building.

- The residential centre (Castelletto, S.Vincenzo, Foce, Brignole): this is the heart of Genoa's middle class, an area that continues to be among the wealthiest in the city (in terms of education level, employment rate, housing conditions), although there is data indicating growing social exposure and vulnerability, due in particular to ageing, an increase in NEETs and a reduction in property values, perhaps more due to a lack of demand proportional to supply than to a deterioration in urban conditions.
- Val Bisagno — from S.Fruttuoso to Marassi - Molassana, passing through Quezzi (from 44 to 61) — is the area of the struggling middle class. Here there is a concentration of stable families, average levels of education and a fairly stable property market, but the burden of ageing and economic vulnerability is growing. The hardship indices are not skyrocketing, but they are showing signs of slow erosion: ageing is more acute than in other central areas; the unemployment rate is closer to that of Ponente than to other areas of Levante, and NEETs are exploding as elsewhere in the city.
- The Levante — from Albaro to Nervi (62 onwards) — is the wealthiest and most attractive part of the city. The socio-economic indicators are clearly positive: high levels of education, low unemployment, property values above €3,000/m². The ageing population is very marked, but this is offset by a good quality of life and the ability to attract new residents with medium-high incomes. This is the Genoa of income, where economic stability is accompanied by growing social and generational isolation.

Figure 1: Map of the seven socio-economic and demographic macro-areas of Genoa

If we consider the stock data for 2021, we see 'peaks' in the indicators, located in specific neighbourhoods and referring to certain processes, which we describe briefly below:

Ageing in Levante

The old-age index in Genoa is among the highest in Italy, with a city average of 264.7 elderly people per 100 young people. However, there are significant internal differences: the hillside and inland neighbourhoods of Levante (Castagna, Bavari, Apparizione, Crevari, Nervi) exceed 350 points, making them areas with very high senility and low birth rates. In contrast, some areas of Valpolcevera and the historic centre (S. Quirico, Certosa, Pre', Morego) maintain indices below 150, thanks to the presence of younger families and a higher incidence of foreign population. The ageing of the population is therefore a widespread phenomenon but with varying intensity, more acute in the residential neighbourhoods of Levante and more mitigated where the immigrant population contributes to rejuvenating the age structure.

Multicultural West

The incidence of foreigners, averaging 10%, shows one of the most marked discontinuities in the entire picture. The Certosa and Sampierdarena neighbourhoods have values three times higher than the average, up to 25-30%, on a par with the neighbourhoods of the historic centre, while the hilly and residential areas (Apparizione, Bavari, S. Eusebio, Crevari) remain around or below 2%. The geographical distribution of foreigners coincides with historically industrial areas or areas with lower rents, resulting in significant spatial segregation: in affluent neighbourhoods, the foreign population remains marginal, while in Ponente and the historic centre, it constitutes a structural component of the resident population.

NEETs double, especially in Ponente

The distribution of young people not in employment, education or training (NEET) is particularly significant. With a municipal average of 17.7%, the phenomenon presents extreme values ranging from around 13% in affluent areas (Albaro, Carignano, Nervi, Apparizione) to peaks of 25-28% in the Ponente neighbourhoods (Sampierdarena, Cornigliano, Certosa, Campi). The risk of youth exclusion therefore follows the same pattern as economic vulnerability and low education, confirming the territorial concentration of social hardship. In neighbourhoods with a high incidence of foreigners and unemployment, NEET appears to be a structural indicator of marginalisation rather than a temporary situation.

Analysis of the data by neighbourhood, based on the latest census, also reveals significant 'cleavage' between the seven macro-areas, which is particularly pronounced when considering the 'extremes of the city', Levante and Ponente/Medio Ponente. In particular:

Educational inequalities

The percentage of adults with a diploma or degree (73% on average) is one of the most serious indicators of socio-territorial division in the city. In the neighbourhoods of Albaro and Carignano, the percentage of the population with a medium-high level of education exceeds 85%, while in working-class areas (Campasso, Cornigliano, Teglia) it falls below 55%. This creates a real educational dualism, consistent with differences in income and property values. In the most vulnerable neighbourhoods, low levels of education fuel vicious circles of precariousness and unemployment, making it more difficult for young people to access the labour market.

Employment inequalities

The unemployment rate, stable at an average of 7.9% for the municipality, hides a highly asymmetrical distribution: Albaro, Carignano, Quarto and Sturla have rates below 6%, while Campasso, Cornigliano, Certosa and Campi exceed 13%. Unemployment follows a geographical gradient consistent with the socio-economic one: low in the Levante and central districts, high in the Ponente and areas of old industrialisation. Here too, there are very strong correlations with education, the presence of foreigners and the spread of economic hardship.

Housing inequalities

The average property value confirms the dual nature of the city. With an average of €1,750/m², prices range from over €2,800-3,000/m² in the areas of Albaro, Quarto, S. Giuliano and Nervi to less than €1,000/m² in the western neighbourhoods (Cornigliano, Sampierdarena). This is a difference of more than three times, reflecting the territorial roots of social inequalities. This is associated with the incidence of families in potential economic hardship, which varies from 13% in residential neighbourhoods to 25% in working-class areas. The two variables have an almost perfect inverse correlation: where property values are high, hardship is minimal and vice versa.

Interesting data also emerges when considering the (limited) flow data available at neighbourhood level for the period 2011-2021.

In recent years, Genoa has seen an internal divide between areas undergoing consolidation and areas undergoing progressive impoverishment.

In the west, from Crevari to Sestri, the population remains stable or is declining slightly, but ageing is accelerating and the proportion of elderly people living alone is growing by more than 10%. Young families are declining, property values are falling in suburban areas and the number of young people out of work or education is increasing. The quality of housing remains good, but the loss of social vitality and the increase in youth unrest point to a fragile balance.

The situation is different in the Medio Ponente area, where Cornigliano, Campasso and Sampierdarena have the worst indicators. Here, the population is falling by more than 10%, NEETs and unemployment are rising sharply, property values are falling by more than 15% and the proportion of vulnerable families is increasing. This is the area most exposed to urban poverty, with a productive fabric that still lacks a stable replacement for abandoned industrial activities.

In the central hills of Rivarolo, Begato, Bolzaneto, Lagaccio and Oregina, the trend is towards progressive depopulation and loss of functions. The population is declining, the number of elderly people living alone and inactive young people is increasing, and the average level of education is falling. These areas, which began as working-class neighbourhoods and have now been affected by decades of marginalisation, represent the most complex area to regenerate because they combine economic fragility and territorial isolation.

The historic centre, on the other hand, is showing signs of demographic recovery: neighbourhoods such as Maddalena, Pré and Molo are gaining residents and property value (particularly Molo), in some cases by more than 15%, thanks to the arrival of foreigners, students and young workers. However, this regeneration is not neutral: gentrification and conflicts over the use of space are on the rise, and internal inequality between redeveloped streets and still-degraded areas is widening, with the risk of displacement for traditional residents.

In Val Bisagno, which includes Quezzi, San Fruttuoso and Marassi, signs of contraction prevail. The population is declining in almost all neighbourhoods, NEETs and families in economic hardship are increasing, property values are falling by up to 15%, and the number of elderly people living alone is multiplying. This is the Genoa of fragile normality, where the middle class is shrinking and vulnerability is becoming widespread, less visible but structural.

The Levante, from Sturla to Nervi, remains the most stable area, with a stable population, a growing property market and improving social indicators. However, this stability comes at a cost in terms of accessibility: rising prices and a reduction in rental accommodation are making the eastern neighbourhoods increasingly exclusive, with a social composition skewed towards the elderly and wealthy. Some indicators, such as the city's highest seniority rate and the increase in NEETs, also point to signs of fragility in this area.

Taken together, these phenomena paint a picture of a segmented city in which vulnerability is concentrated in the western and inland areas, while the centre and the eastern areas accumulate economic and symbolic capital, albeit with various contradictions. Variations of more than 10% in many key indicators – employment rate, incidence of NEETs, property values, families in difficulty – show that internal disparities are no longer marginal but structural. Genoa therefore presents itself as a mosaic of competing territories: some areas are being repopulated thanks to new migratory flows or redevelopment processes, others are becoming depopulated and ageing, and still others are closing themselves off in selective affluence. The future of the city will depend on its ability to reduce these distances, stitching the six Genoas together into a unified vision that balances attractiveness, equity and social cohesion.

4.2 The Context of Friuli Venezia Giulia (FVG) UTE

4.2.1 The territorial context

Friuli-Venezia Giulia (FVG) Region occupies a strategic position in Italy's north-eastern borders, with Austria to the north, Slovenia to the east, and the Adriatic Sea to the south. The landscape is remarkably varied, descending from the Alpine mountain range in the north, which constitutes 42.5% of the territory, through hilly areas (19.3%), down to the plain and coastline that make up the remaining 38.2%. The region spans a wide variety of climates and landscapes, ranging from Alpine continental in the north, to the mild Oceanic in the south. Considerable efforts are placed on preserving the natural heritage of the region. Its varied terrain hosts significant biodiversity, which is protected through a network of parks, nature reserves, and biotypes that cover 19% of its total land area. The land itself supports a mix of uses, including specialized agriculture and tourism, both of which are vital components of the local economy.

The urban areas selected as the UTE-FVG (Unità Territoriale di Elaborazione - Friuli Venezia Giulia) are outlined in Figure 2, and represent important economic, historical and cultural centres. The city of Trieste, the largest city in the Friuli Venezia Giulia Region, is of fundamental economic importance due to the presence of ports and other infrastructures, which make it a strategic site for trade and tourism, in addition to its high historical relevance. Monfalcone is an industrial site, with several shipyards and a textile and chemical production centre. The cities of Grado and Lignano are among the leading Italian seaside touristic centres. The city of Lignano is a primary touristic site, reaching a population of several hundred thousand visitors during the summer period. The remarkable variability in the number and composition of the population throughout the year (up to 20 times compared to resident population) makes it an area of special interest for investigating the temporal variability of risks, which is relevant to several other coastal tourist cities. Moreover, between Grado and Lignano there is an extensive lagoon, characterised by a peculiar and fragile ecosystem, with a high degree of vulnerability due to its direct connection with the Adriatic Sea basin.

The complex territorial system of Friuli-Venezia Giulia is exposed to a variety of natural hazards, which are briefly listed in the following. Earthquakes in particular, which can trigger cascading disasters such as tsunamis and landslides, are especially relevant for multi-risk assessment. Physics-based modelling of earthquakes and related cascading hazards provides the essential basis for defining plausible, yet unobserved, multi-hazard and risk scenarios. A database of physically sound, systematically computed scenarios, provides information useful towards informed emergency decisions and preparedness multi-hazard mitigation strategies. Moreover, it provides the basis for assessing the complex interactions between multiple hazards and the exposed systems (both physical and social environments), which can be used to develop plausible multi-risk storylines, as described in the following.

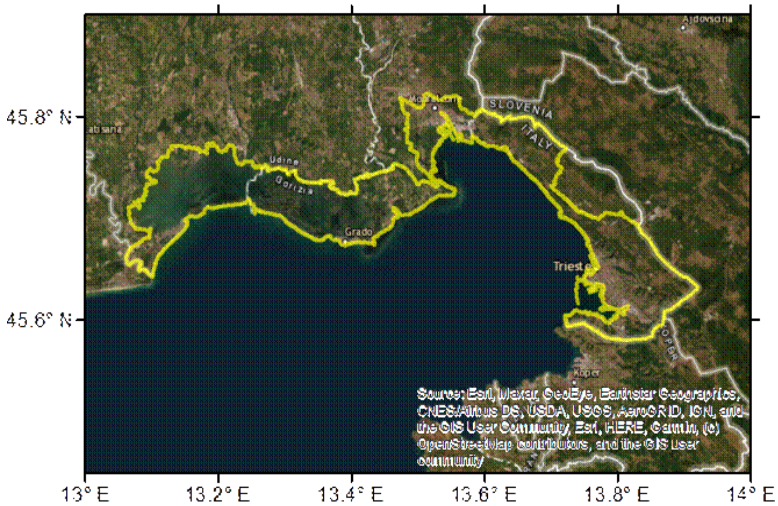

Figure 2: Map of the Elaboration Territorial Unit - Friuli Venezia Giulia (UTE-FVG), located along Northeast Adriatic Sea.

The FVG region is located in northeastern Italy, at the junction between the eastern segment of the Southern Alps and the northwestern segment of the External Dinarides, and its geodynamics is controlled by the convergence of the Adria microplate and the Eurasian plate (Bressan et al., 2019 and references therein; Panza et al., 2014). Throughout history, the FVG region has been struck by a number of destructive earthquakes, the most recent one being the 1976 Friuli earthquake (M6.4), which caused intensities up to X on the on the Mercalli-Cancani-Sieberg (MCS) in Gemona, Venzone, and Trasaghis, resulting in approximately 989 fatalities. Seismicity is not uniform across the region; the most active area lies along the boundary between the mountains and the plain, particularly in the Gemona and Tolmezzo area, with significant historical events occurring in 1389, 1908, and 1928 (MCS intensities VIII-IX) (Figure 3). In contrast, the plain exhibits a much lower seismic hazard. Since 1977, a dense seismic network of over 40 stations has been operated by OGS Seismological Research Centre for real-time monitoring of seismicity (https://smino.ogs.it/it/).

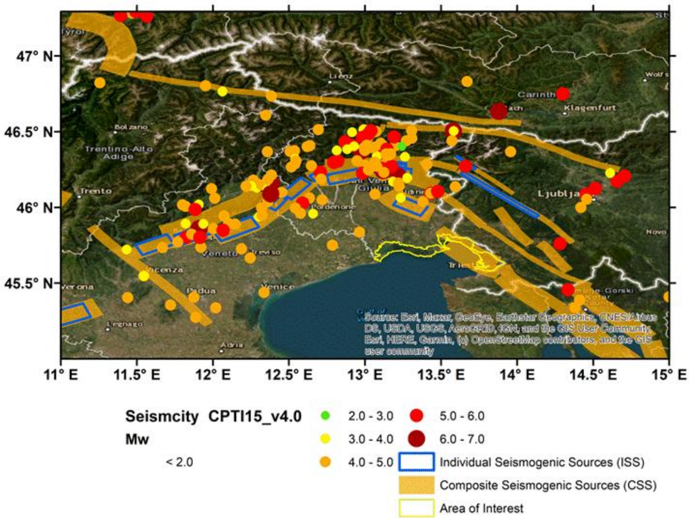

Figure 3: Distribution of seismic activity in the FVG region and its surroundings, including the UTE-FVG the coastal area (in yellow), for the period from 1005 to 2020 (adapted after CPTI15 V4.0). Individual and composite seismogenic sources are from DISS3.3.1 database.

As shown in Figure 4, the current seismic hazard map of Italy, which has been defined according to the Probabilistic Seismic Hazard Analysis (PSHA) and was adopted in 2006 (Ord. PCM 20.03.2003, n. 3274, All. 1), the FVG region is characterised by a relatively high seismic hazard. However the hazard is lower in the coastal area, and the map indicates acceleration values ranging from 0.05g in the western part of the UTE-FVG (i.e. Lignano) and up to 0.175g to the east (i.e. Trieste and its vicinity). The seismic classification of the Friuli Venezia Giulia territory (B.U.R. n. 20, 19 May 2010) assigns all of the territory of the UTE-FVG to Zone 3, which corresponds to an acceleration in the range 0.05g-0.175g. Still, the Neo-Deterministic Seismic Hazard Assessment (NDSHA), which defines the hazard as the envelope of a broad set of modeled scenarios, indicates that the estimated maximum horizontal acceleration (design ground acceleration) within the UTE-FVG might reach values as high as 0.30g (see Panza et al., 2014), suggesting a potentially higher seismic hazard, particularly when local site effects are considered.

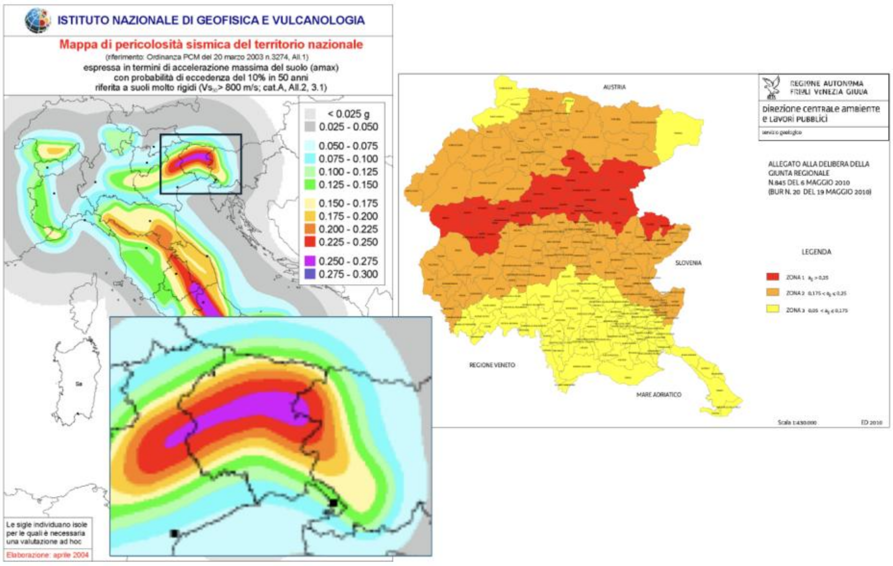

Figure 4: Current seismic hazard map of Italy (http://zonesismiche.mi.ingv.it/mappa_ps_apr04/italia.html), with a zoom on FVG region (left) and seismic classification of the FVG municipalities (right).

Besides causing direct impacts and damage, earthquakes can also trigger cascading events, such as tsunamis or landslides; these multi-hazard events are described in detail afterward, in the sections related with multi-risk scenarios modeling. Although strong tsunamigenic earthquakes are infrequent in the Adriatic Sea, the FVG-UTE coastline is exposed to tsunami hazard. Historical records indicate that up to 27 tsunamigenic events occurred in the Adriatic over the past 600 years (12 of which are unreliable, or not due to earthquakes), with sources mostly on its eastern side. While significant tsunamis are rare in the shallow Northern Adriatic, historical evidence points to impactful events in the years 1348 and 1511 (e.g. Maramai et al., 2021).

Landslides and rockfalls are significant geohazards in the FVG region as well as in the UTE-FVG territory (Figure 5), particularly in its areas characterised by high reliefs and variable topography (e.g. Trieste). Along the coast, they can generate cascading hazards (e.g. rockfalls can also trigger tsunami), driven by factors like heavy rainfall, steep slopes, presence of faults, and specific geological formations.

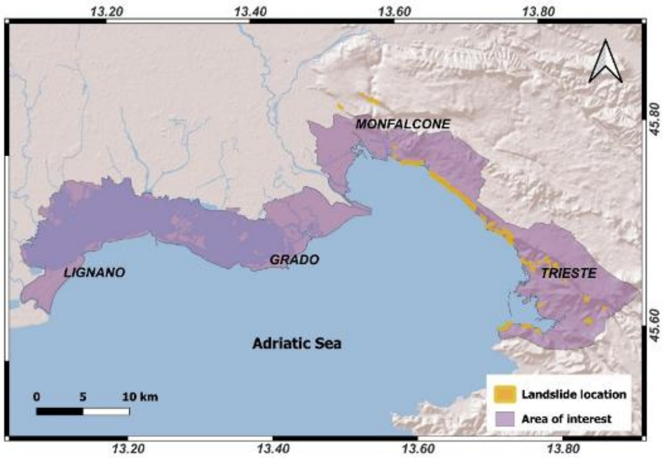

Figure 5: Landslide hazard zones along the coastal area of the UTE-FVG, as provided by IFFI database available via the ISPRA website (https://www.isprambiente.gov.it/it/progetti/cartella-progetti-in-corso/suolo-e-territorio-1/iffi-inventario-dei-fenomeni-franosi

The UTE-FVG coastal area is also vulnerable to land subsidence, which exacerbates the effects of sea-level rise due to climate-change. The northern Adriatic coast is the lowest-elevation coast in the Mediterranean. Studies using levelling data and SAR-based interferometry (e.g., Envisat ASAR, ERS1/2) show heterogeneous subsidence rates along the coast. While many studies investigated the land subsidence in the north Adriatic coastland areas, only few of them were focused on the subsidence along the UTE-FVG coast (e.g. Da Lio and Tosi, 2018). The highest rates (~3–4 mm/year) are observed at the Tagliamento River delta, Bibione, and Lignano. Grado and Monfalcone exhibit moderate rates of 2-2.5 mm/year, while the northern part of the coast is more stable.

The Fluvial Flood hazard maps for the UTE-FVG region (Marked by yellow color) regions were developed by ISPRA within mosaic national maps in December 2017 (https://idrogeo.isprambiente) and classified based on 3 scenarios: high hazard (P3) with return time between 20 and 50 years (frequent floods), medium hazard (P2) with return time between 100 and 200 years (infrequent floods) and P1 (low probability of floods or extreme event scenarios) as shown in Figure 6.

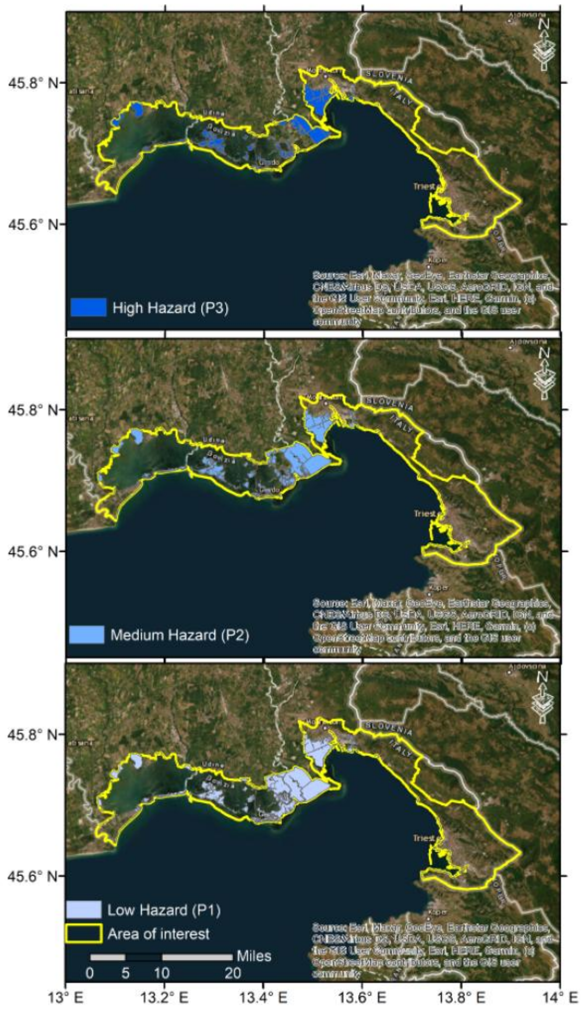

Figure 6: Clipped National mosaic of flood hazard zones developed by ISPRA in 2017 (https://idrogeo.isprambiente) and classified into 3 scenarios P1, P2, and P3.

The Adriatic Sea is a hotspot for Meteorological Tsunamis (Meteotsunamis) — namely, long waves generated by atmospheric pressure disturbances - and Storm surges. These events can cause coastal flooding and significant damage, as demonstrated by severe storm surges that impacted the UTE-FVG coast in October and November 2023. These two events, though not causing human losses, heavily damaged the coastal assets and caused disruption of activities. According to the local newspapers the preliminary estimation of direct losses is in several millions of Euros. In Muggia the historic centre was submerged by 15 cm of water; similarly, in Grado it caused interruption of traffic and school activities. In Trieste the high water level and the unusual strength of the storm affected the banks, particularly the Barcola seafront, causing extensive damage and resulting in emergency closure of the road along the sea, which is one of the main access ways of the city.

The karstic terrain in the internal part of the UTE-FVG region is also susceptible to Wildfires, particularly during hot, dry, and windy conditions. A significant event occurred in July 2022, when fires originated in the area between Monfalcone and Doberdò del Lago, and affected a wide area at the borders between Italy and Slovenia, lasting for days and requiring even activation of the EU Copernicus Emergency Management Service for damage assessment. This wildfire event (which marks the reports of many stakeholders) caused disruption of circulation along Highway A4, which is one of the main connections between Italy and Slovenia, as well as the main access way to Trieste. Wildfires are a major threat also for the green areas that characterise wide territories of the coastal areas of UTE-FVG. For instance, the pinewood of Lignano Sabbiadoro, a protected site of ~118 ha representing a remnant of the coastal dune–pinewood ecosystem of the Tagliamento delta peninsula, is very susceptible to wildfires. This problem is relevant to other similar tourist coastal areas of the UTE-FVG and elsewhere along the Adriatic coasts.

4.2.2 Socio-economic and demographic context

Demographic overview

Across the four municipalities, demographic indicators for the period 2020-2023 show distinct population dynamics that influence local social structures and, consequently, the capacity of communities to maintain stability and provide support networks.

In Lignano-Sabbiadoro, the birth rate remains consistently low, fluctuating between 4,9 and 7,3 per thousand, while mortality increases and exceeds 11 per thousand in 2021 and 12,4 per thousand in 2022. These trends result in a gradual ageing of the resident population and a reduced generational turnover. The small size of the community amplifies this effect, as each demographic shift weighs proportionally more on the overall structure.

Grado presents an even more accentuated pattern over the same period. Birth rates remain very low, between 4,2 and 4,7 per thousand, while mortality reaches exceptionally high levels, peaking at 24,3 per thousand in 2021. The combination of low births and high deaths produces a rapid ageing process and a significant contraction of the working-age population. This dynamic affects not only demographic sustainability but also, indirectly, the potential tax base and the resources available for welfare and essential services. A smaller active population weakens the capacity of the municipality to maintain adequate levels of service provision.

In Monfalcone, the indicators outline a comparatively more dynamic demographic structure. Birth rates remain consistently above 9 per thousand, with values between 9,1 and 11,1 per thousand, significantly higher than those observed in Lignano and Grado. Mortality levels, ranging between 12 and 13 per thousand, are stable and well below the extreme values recorded in Grado. Although the natural balance remains negative, Monfalcone benefits from a comparatively younger population and a more substantial generational turnover. These elements mitigate demographic vulnerability and help sustain the active population.

Trieste occupies an intermediate position. Birth rates remain low, between 5,9 and 6,4 per thousand, while mortality declines only slightly, from 16 per thousand in 2020 to 14,2 per thousand in 2023. These values confirm that the city is characterized by a structurally ageing population. The ageing index remains very high, fluctuating between 260 and 265, while indicators related to the renewal of the working-age population increase only modestly, from 166,1 to 173,3. This limited growth indicates that the active population is ageing and only partially replaced by younger cohorts. Taken together, these trends position Trieste closer to Grado than to Monfalcone, with a consolidated pattern of demographic imbalance that affects long-term resilience and the sustainability of local welfare systems.

Differences between municipalities also emerge clearly from household characteristics and family-based indicators.

In Lignano-Sabbiadoro, the average age increases steadily, reaching 48,7 years in 2024, while the dependency ratio remains stable around 56. Households are relatively few, approximately 3.600 units, and small, with fewer than two members on average. This configuration limits the availability of internal support networks. The number of children per fertile woman remains low, between 16 and 17, consistent with the modest birth rates and indicating limited reproductive capacity. These factors, combined with the municipality's marked seasonality, contribute to a demographic structure in which a small resident population is paired with small households and limited turnover.

In Grado, these dynamics are even more accentuated. The average age exceeds 52 years, and the dependency ratio reaches 71 in 2024, the highest among the coastal municipalities. Households number between 4.200 and 4.300, but their average size drops to 1,77 members, indicating very small family units. The number of children per fertile woman remains low, between 15 and 16. These indicators point to a strongly ageing population and minimal household structures. This combination reduces internal support capacity and may create pressure on services, particularly in the context of significant tourism inflows.

Monfalcone shows a different profile. Despite being a large and dense municipality, it records the lowest average age, 44,9 years in 2024, and the highest number of children per fertile woman, between 25 and 27. Households are numerous, more than 13.000 units, and larger on average, with 2,19 members in 2023. This structure indicates comparatively stronger demographic reproduction and broader internal support networks. As already noted in relation to foreign residents, demographic vulnerability in Monfalcone arises less from ageing processes and more from the challenges associated with managing a heterogeneous and densely populated urban community.

Household dynamics reinforce these trends. Monfalcone shows growth both in the number of families and in average household size, indicating increasing demographic stability. Lignano shows only a slight increase in household numbers. Grado, consistent with the negative demographic trends already observed, shows a contraction in both the number and size of households.

In Trieste, demographic indicators describe a more balanced yet structurally fragile configuration. Birth rates remain low, between 5,9 and 6,4 per thousand, while mortality remains high. The ageing index remains extremely elevated across the period, between 260 and 265. Indicators of working-age replacement increase modestly, from 166,1 to 173,3, signaling that generational turnover is weak. The dependency ratio remains stable, moving from 65,1 to 63,7, suggesting a persistent demographic burden on the active population.

Household indicators confirm this pattern. The average age stays around 49 years, and the number of households remains above 105.000. Family size is consistently very small, between 1,85 and 1,87 members, indicating a high prevalence of single-person and two-person households. This reduces the availability of internal support networks and limits the community's capacity to absorb demographic or social pressures. Overall, these elements place Trieste closer to Grado in terms of demographic structure, despite its significantly larger population base.

Urban structure overview

According to 2011 census data, Lignano-Sabbiadoro exhibits a substantial building stock, with 4.246 structures and more than 27.000 housing units, contrasting with a small resident population of roughly 6.900 inhabitants. This imbalance reflects the municipality's pronounced tourism orientation and creates vulnerability because a small resident community must oversee and maintain a built environment designed for seasonal peaks. Land consumption is high, at 32,5 percent, within a limited territory of 15,4 square km exposed to coastal hazards such as storm surges and erosion.

In the same year, Monfalcone shows a different pattern. With 4.854 buildings and 14.697 housing units, it is a dense urban center with a residential density of 1.493 inhabitants per square km. Vulnerability arises mainly from the age and condition of the building stock: 64 structures are classified as ruined and 335 as in very poor condition, representing about 16 percent of residential buildings. Land consumption is also high, at 46,2 percent, within a territory of 20,4 square km. However, the large resident population, more than 30.000 inhabitants, provides a significant resource for emergency response and service provision.

Grado occupies an intermediate position. Its 2.041 buildings and 12.757 housing units include a large share of older structures: 172 built before 1919 and 232 between 1919 and 1945. Despite the age of the stock, only 19 buildings are classified as ruined and 195 as in very poor condition, around 11 percent of the total. The resident population of roughly 7.500 inhabitants is spread across a very large territory of 119 square km, resulting in a density of about 63 inhabitants per square km. This dispersion complicates service delivery and emergency operations, particularly in peripheral areas.

Trieste presents a distinct configuration. With 27.244 buildings and 22.638 residential units in 2011, it is the largest urban center among the municipalities considered. It has an extensive historical building stock, with more than 7.000 structures built before 1919 and more than 6.000 built between 1919 and 1945. Land consumption is moderate, around 20 percent, but population density is high, at 2.415 inhabitants per square km. Vulnerability in Trieste arises from the interaction between an ageing-built environment and a complex urban morphology characterized by steep slopes and narrow streets, which can hinder emergency interventions and require substantial maintenance efforts.

The 2021 data confirm these profiles. In Lignano, 4.908 residential buildings are recorded, but only 1.863 are occupied by residents; many are unoccupied or used as second homes. The main vulnerability remains seasonal fluctuation, with strong population peaks in summer and limited social support networks in winter.

Monfalcone remains the densest municipality, with 13.405 households and 4.675 residential buildings. The presence of 559 collective dwellings and 1.462 foreign-resident households indicate social heterogeneity and the possible formation of localized disadvantage. More than 3.600 unoccupied dwellings signal areas weakly integrated into community life. Nonetheless, demographic size and infrastructure provide comparatively strong capacity for crisis management.

Grado shows a high intensity of use of its building stock, approaching two households per residential structure. Low land consumption (3,6 percent) and low density remain favorable conditions, but territorial dispersion continues to pose challenges for civil-protection activities, while the ageing building stock requires ongoing maintenance.

Overall, the four municipalities show distinct vulnerability profiles: Lignano combines a small resident population with an oversized tourism-driven built environment; Monfalcone presents high density and ageing buildings but benefits from a large and structured population; Grado shows dispersed settlement and strong ageing dynamics; Trieste combines high density, extensive historical structures and geomorphological constraints, shaping a complex vulnerability configuration.

Territorial services and functional accessibility

In Lignano-Sabbiadoro, with over 3.2 million tourists overnight stays in 2024 (approximately 40% of the regional total tourism), vulnerability stems from the strong dependence on seasonal and international inflows. The summer peak of roughly 900,000 overnight stays amplifies the imbalance between a small resident population and extremely concentrated tourist pressure over just a few months. Grado records lower absolute numbers (1.39 million overnight stays, about 17% of the regional total), yet an even higher share of foreign visitors (78%). Here, vulnerability is linked to the reliance on a highly selective international tourism market and to the effects of seasonality on a small and ageing resident community. The prevailing tourist segments appear to be German and Austrian visitors.

In Monfalcone, tourism plays only a marginal role. Instead, social vulnerability is shaped by the sizeable foreign resident population, which exceeds 9.500 people, largely of Asian origin. In this case, criticalities arise not from seasonality but from integration challenges within a densely populated and socially complex urban environment.

Temporary and commuting populations can be estimated through official mobility data, whereas irregular or unregistered individuals remain outside census systems, complicating emergency communication. Without monitoring by institutions such as Caritas or the Prefectures, these groups may not receive alerts and could represent an unexpected burden during evacuation or shelter operations.In sum, while Lignano-Sabbiadoro and Grado share vulnerabilities tied to dependence on foreign tourism and strong seasonal imbalances, Monfalcone exhibits a different profile, where the main criticalities relate to the integration of foreign residents (cultural mediation, multilingual alerts and drills, etc.) rather than tourist inflows.

Lignano-Sabbiadoro, Grado, Monfalcone and Trieste present very different accessibility profiles, shaped by their geography, size and mobility demands. These differences influence how each municipality responds to pressure on its transport system and how vulnerable it may be during emergencies.

Lignano-Sabbiadoro relies entirely on two access routes: the SR354 and Bevazzana bridge. This limited configuration makes the town particularly sensitive to interruptions or congestion episodes. Public transport is mostly seasonal and designed around tourist peaks, since the municipality is too small to sustain a stable urban service throughout the year. There is no direct railway connection, and wider regional mobility depends on the station of Latisana-Lignano-Bibione, located about 17 km away. Overall, Lignano shows the highest degree of fragility in terms of access and redundancy.

Grado is reached mainly through the SR352 and the SP19. Both roads cross lagoon areas where the risk of hydraulic instability and storm surges is significant. The town offers a small but continuous urban bus service and a more structured extra-urban network, although both are adjusted seasonally. Like Lignano, Grado has no direct rail link and depends on Cervignano del Friuli for long-distance mobility. The presence of only two main road axes limits the room for maneuvering during evacuations or exceptional operations.

Monfalcone has a far more articulated transport structure. The A4 motorway, the SR305, the SP19 and several provincial roads create multiple alternative routes and provide a good degree of redundancy. Public transport is extensive and responds to the needs of both residents and the large number of commuters linked to industrial activity in the area. The municipality lies directly on the Venice–Trieste railway line and has recently expanded its mobility offer with new maritime connections. It records the highest annual bus service mileage among the four municipalities. Although some bottlenecks remain, particularly on the A4, Monfalcone is generally the most robust in terms of accessibility.

Trieste has the widest and most diversified transport system. Road access depends on a few strategic corridors, including the A4, the RA13 and RA14 routes towards Slovenia, and the SS14 Costiera. These links are essential but cross areas that are exposed to landslides, rockfalls and storm surges. The city benefits from the region's most extensive urban bus network, international rail connections through Trieste Centrale and seasonal maritime services. Trieste Airport, located around 35 km away and accessible by both motorway and rail, further strengthens regional and international connectivity. At the same time, the concentration of movement on a handful of corridors and the physical constraints imposed by the Karst plateau make the system sensitive to disruption, despite its overall richness.

In general, Trieste is the most interconnected and multimodal center, while Monfalcone offers the best redundancy compared to its size. Grado and Lignano-Sabbiadoro remain more vulnerable because their transport systems rely on very few access routes and lack railway infrastructure. These differences shape each municipality's capacity to manage emergencies, organize evacuations and maintain reliable mobility during critical events.

The distribution of hospital facilities reveals marked contrasts among the municipalities. Monfalcone is the best served: the municipal hospital is located less than two km from the town centre and is complemented by rapid access to the hospitals of Gorizia (around 23 km) and Trieste (approximately 37 km). This configuration ensures short response times for emergencies and specialist care.

Trieste offers an even denser concentration of healthcare infrastructure, since the city hosts the Cattinara Hospital (Maggiore) and the IRCCS Burlo Garofolo, all situated within or just beyond the urban core and generally reachable from the city centre in less than two km. This proximity, combined with the city's role as a regional hub, guarantees the highest overall level of healthcare availability among the four municipalities.

Lignano-Sabbiadoro presents a more limited situation. Its nearest hospital is Latisana, approximately 17 km away, while the facilities in Palmanova and Udine lie between 48 and 65 km from the town. More remote hospitals such as San Daniele and Tolmezzo exceed 70 km and play only a marginal role in routine access. These distances become particularly problematic during the summer season, when the population increases sharply and external facilities face a disproportionate demand. During the summer season, Lignano benefits from a seasonal emergency unit located in the town itself (approximately 2.5 km from the centre), which partially offsets the municipality's structural dependence on external hospitals. Year-round care is provided by the medical guard/out-of-hours service based in Latisana, also located around 17 km away.

Grado is the most peripheral. Its closest hospital is in Monfalcone, at around 26 km, while all other major facilities (Trieste and Gorizia) range from roughly 40 to 66 km. This spatial configuration creates a structural delay in emergency response times and increases the risk of isolation during large-scale events that simultaneously affect several coastal areas. The town relies on a seasonal tourist medical service located within the local health district, only about 550 metres from the centre. This service improves local response capacity during peak tourist months but does not compensate for the longer travel times required to reach full hospital care.

Overall, Trieste and Monfalcone enjoy the strongest healthcare coverage, with hospitals located within a two-kilometre radius of the urban core. Lignano-Sabbiadoro combines moderate distances with intense seasonal population pressure, which heightens saturation risk. Grado remains structurally disadvantaged due to its geographic peripherality and longer travel times to all major healthcare centres

In terms of social vulnerability, public schools can play an important role in promoting community engagement and strengthening local capacities. They also serve as channels for disseminating rules and procedures to be followed in emergency situations. From the perspective of risk exposure, when school buildings are well maintained they can function as gathering points during an emergency. Across the three municipalities, the number of state-owned school buildings that can operate as emergency hubs varies markedly: 8 in Lignano-Sabbiadoro, 5 in Grado and 24 in Monfalcone.

The distribution of school facilities and their users reflects broader demographic patterns. Lignano-Sabbiadoro and Grado each have seven state schools, yet the size and composition of their student populations differ. Lignano-Sabbiadoro hosts 882 students overall, while Grado has 541. Monfalcone shows a much larger educational system, with 21 schools and almost 4.000 students. These differences align with the demographic dynamics of the area and help explain Grado's lower numbers when considering school-age population, natural balance and net migration.

A more detailed breakdown by school level illustrates how these differences take shape. In Lignano-Sabbiadoro, early childhood education includes two preschools with 144 children, followed by one primary school with 246 pupils, one lower secondary school with 220 students and three upper secondary schools enrolling 272 students. Grado has three preschools with 118 children, two primary schools with a combined total of 192 pupils, one lower secondary school with 130 students and one upper secondary school with 166 students. Monfalcone, as the main urban centre, hosts eight preschools with 596 children, five primary schools with 1.233 pupils, three lower secondary schools with 738 students and six upper secondary schools with roughly 1.428 students, although one institute reports incomplete data.

Patterns in teaching staff mirror these structural differences. Lignano-Sabbiadoro employs 196 teachers, Grado 286 and Monfalcone 559. The distribution of support teachers is equally informative: 39 in Lignano-Sabbiadoro, 74 in Grado and 161 in Monfalcone. These values can serve as a proxy for both social vulnerability and the responsiveness of local welfare systems. The high number of support teachers in Grado, relative to its total student population, may indicate a greater presence of students with certified disabilities, special educational needs or learning difficulties, which could suggest higher social vulnerability. At the same time, this figure may instead reflect a more effective welfare and educational support system, capable of identifying and meeting special educational needs more systematically. From this perspective, the lower proportions observed in Lignano-Sabbiadoro and Monfalcone do not necessarily reflect fewer needs, but may indicate gaps in the provision or allocation of specialised support services.

Trieste shows a considerably different educational profile from the coastal municipalities. As the regional capital and largest urban centre in Friuli Venezia Giulia, it hosts a far more extensive and diversified school system, ranging from preschools to specialised secondary and vocational institutes. The scale of the city is also reflected in its educational attainment: roughly 46.000 residents have no qualification or only a primary-school certificate, around 30.000 hold a lower secondary qualification, approximately 61.000 are high school graduates and about 25.000 have a university degree or higher academic title. This distribution highlights both the size and the internal differentiation of Trieste's educational fabric, which is considerably more stratified than that of Lignano-Sabbiadoro, Grado or Monfalcone.

Trieste's demographic structure further reinforces this difference. Its broader population base and concentration of services support a larger school system with more students, teachers and support staff, as well as a greater capacity to identify and respond to special educational needs. Within the regional context, the city functions as a key reference point not only for education but also for health and social services, offering infrastructures and resources that exceed those available in the smaller coastal municipalities.

Socioeconomic overview

The distribution of taxable income shows that the three municipalities share a broadly similar structure, with the largest share of taxpayers concentrated in the intermediate brackets. In Lignano-Sabbiadoro, 30,7 percent of taxpayers fall within the 26.000-55.000-euro range, a proportion slightly lower than that observed in Grado (33,3 percent) and significantly lower than in Monfalcone (38 percent). Lignano, however, differs in the lower brackets: 1.604 taxpayers, corresponding to 28,5 percent of the total, declared less than 10.000 euro, and a further 27,5 percent fall within the 10.000-15.000-euro range. This configuration reflects the strong seasonal component of the local labour market, characterised by discontinuous employment and income concentration during the summer months. The relative weight of the lower-income brackets also indicates that a sizable portion of residents depends on part-time or temporary contracts that do not generate stable contributions throughout the year. As a result, the municipality's tax structure shows a high proportion of taxpayers, but with comparatively modest individual tax bases.

In Grado, the distribution shows a slightly more balanced structure. The 15.000-26.000-euro band is the most represented (33,3 percent), and only 19,3 percent of taxpayers fall below the 10.000-euro threshold. This suggests a workforce that, although ageing, maintains a relatively stable income base. The predominance of middle-income taxpayers (particularly within the 26.000-55.000-euro range, 33,3 percent) reflects the presence of consolidated employment sectors linked to tourism services, small commerce, and pensions. The income structure also mirrors the demographic profile of the municipality, where pension income represents a substantial share of total declared income.

Monfalcone displays the most diversified and structurally robust distribution. The intermediate cohort (particularly 15.000-26.000 euro and 26.000-55.000 euro) account for more than three-quarters of all taxpayers, reflecting a labour market supported by industry, services, and a comparatively large working-age population. Lower brackets are proportionally less represented than in Lignano and Grado, which is consistent with the presence of stable employment contracts and a broader industrial base. The upper-income brackets are also slightly more populated than in the other municipalities, indicating the presence of managerial and specialised professional roles within the local economy.

Trieste displays a markedly different income structure, consistent with its size and role as the main urban centre of the region. With 158.324 taxpayers, it relies on a considerably broader tax base than the other three municipalities combined. The distribution of taxable income remains concentrated in the intermediate brackets: the 26.000-55.000-euro range includes 48.419 taxpayers, corresponding to roughly 37,8 percent of the total, a proportion close to that observed in Monfalcone but on a much larger scale. Lower brackets are also substantial in absolute terms – 33.963 taxpayers (21,4 percent) declare incomes below 10.000 euro – but their relative weight is smaller than in Lignano and Grado. This reflects a more stable labour market and a lower incidence of seasonal or intermittent employment. The higher brackets are also more populated than in the other municipalities. A total of 3.733 taxpayers fall within the 75.000-120.000-euro range, and 1.799 exceed 120.000 euro. These values indicate the presence of a broader upper-income segment linked to the city's administrative, scientific and logistics sectors. Overall, the distribution suggests that, although internal disparities may be more visible due to the population scale, Trieste benefits from a more diversified and structurally resilient income profile.

Differences in fiscal capacity emerge clearly when comparing total tax revenue. Although Lignano-Sabbiadoro records a very high share of taxpayers relative to its population (84,4 percent, 5.765 taxpayers out of 6.833 residents), its total net municipal tax amounts to 23,9 million euro, slightly below Grado (24,5 million euro). This indicates a relatively solid per-capita tax base, but one that remains modest in absolute terms due to the small size of the resident community. The high taxpayer-to-resident ratio suggests that most adults are formally registered as contributors, yet the seasonal labour pattern limits the overall volume of taxable income.

Grado registers a slightly higher net municipal tax (24,5 million euro) generated by 6.449 taxpayers. Although this value is close to that of Lignano, its distribution reflects a larger proportion of pensioners and middle-income earners. This structure produces a tax base that is stable but not particularly dynamic, consistent with the demographic characteristics of an older municipality with a lower incidence of seasonal or temporary employment.

Monfalcone stands apart, with 71,3 million euro in net municipal tax generated by 22.282 taxpayers. This level is substantially higher than in the other two municipalities and reflects both the size of the resident population and the presence of a more diversified labour market. The industrial and service sectors contribute significantly to this result, as does the higher incidence of full-time employment contracts. The difference becomes even more evident when examining municipal surtax contributions: Monfalcone exceeds 1,5 million euro, compared with 53.933 euro in Lignano and 35.402 euro in Grado, indicating a markedly higher fiscal capacity.

Trieste generates 763,3 million euro in net municipal tax, a level far higher than Monfalcone (71,3 million euro), Grado (24,5 million euro) and Lignano-Sabbiadoro (23,9 million euro). The size of this tax base reflects both the demographic weight of the city and the presence of a wider variety of professional and industrial sectors. Additionally, from surtax Trieste generates an additional 27,75 million euro.

The composition of income sources provides additional insight into the socio-economic profile of each municipality. In Lignano-Sabbiadoro, income from employment amounts to 62,0 million euro, followed by pension income (29,5 million euro) and income from property (7,5 million euro). Income from self-employment and entrepreneurship is limited, involving only small groups of taxpayers. This pattern reflects the structure of the local economy, where seasonal employment, tourism, and property ownership play central roles. Pension income accounts for 28 percent of taxpayers, further aligning with the town's progressively ageing population.

Grado shows a similar structure but with a stronger incidence of pensions. Pension income reaches 50,2 million euro and involves 2.644 taxpayers, corresponding to 33,9 percent of all contributors. Employment income remains relevant (64,3 million euro) but is proportionally less dominant than in Lignano and substantially lower than in Monfalcone. Income from property is also significant (4,9 million euro), consistent with a settlement model characterized by second homes and an older demographic.

Monfalcone exhibits a markedly different composition. Employment income exceeds 272,8 million euros, reflecting the municipality's larger industrial and service base and its higher share of active residents. Pension income remains substantial (151,2 million euro) but represents a smaller proportion relative to the size of the working population. Income from property is comparatively limited (9,8 million euro), consistent with a more urbanised context and a lower incidence of holiday homes. The broader distribution across income categories also aligns with the labor market diversification observed in the municipality, where industry, logistics, and services coexist with smaller segments of self-employment.

The composition of income sources helps clarify the socio-economic structure of Trieste. The largest share derives from employment income, which amounts to 2,097 billion euro. This figure reflects the size of the local labour force and the concentration of service activities, logistics, public administration and research institutions in the city. Pension income also represents a substantial component, reaching 1,367 billion euro and involving 61.598 recipients. The weight of this category is consistent with the city's demographic profile, which is characterized by a stable and structurally ageing population.

Income from property amounts to 102,3 million euro and indicates the presence of an extensive and consolidated housing stock. Self-employment and entrepreneurial income show significant diversification. Income from self-employment accounts for 136,27 million euro, while income deriving from business and partnership activities exceeds 170 million euro when the relevant categories are combined. A total of 7.010 taxpayers report income in these autonomous or entrepreneurial forms, confirming the presence of a broad range of small-scale economic activities.

Taken together, these elements describe a socio-economic context that differs markedly from that of the coastal municipalities. Unlike Lignano, where seasonal employment shapes a large part of the income structure, or Grado, where pension income has a dominant weight, Trieste presents a diversified urban economy sustained by multiple sectors and a wide range of professional profiles.

4.2.3 Tourist dimension

The FVG region constitutes one of the most dynamic and diversified tourism systems in north-eastern Italy, characterised by a distinctive combination of Alpine and coastal environments, historical towns, and cultural heritage sites. Over the past decade, this territorial diversity has supported a continuous expansion of tourist flows, interrupted only by the pandemic shock in 2020. According to ISTAT data (2014–2020), total overnight stays increased from approximately 7.6 million in 2014 to more than 9 million in 2019, corresponding to an overall rise of nearly two million stays and an average annual growth rate of around 4–5%.

This upward trajectory was largely driven by the steady growth of international tourism, which rose from 4.1 million to over 5.1 million stays during the same period, consistently surpassing the domestic component. Although domestic tourism also expanded—mainly fuelled by visitors from Veneto, Lombardy, and Trentino-Alto Adige—the international market played a decisive role in shaping the regional tourism profile.

In 2019, foreign visitors accounted for more than 55% of total stays, led by Austrian and German tourists, followed by visitors from Slovenia, the Czech Republic, and Poland. This predominance reflects the Region's geographical proximity to Central Europe and the effectiveness of cross-border promotion and transport integration policies.

The year 2020 marked a turning point, with total stays declining to 4.7 million (–48% compared with 2019) and international arrivals collapsing to fewer than 1.9 million overnight stays. The contraction particularly affected urban and coastal destinations—Trieste, Lignano Sabbiadoro, and Grado—which were heavily dependent on international markets. Although domestic tourism showed a temporary recovery during the summer months, it was insufficient to offset the overall losses.

Despite this setback, from 2021 onwards, Friuli-Venezia Giulia experienced a rapid rebound, initially driven by the domestic segment and subsequently supported by the gradual return of traditional European markets. By 2023, the number of overnight stays had already surpassed pre-pandemic levels (ISTAT, 2024), suggesting a structural capacity for regeneration within a diversified territorial system.

The tourism profile of the Region is characterised by a balance between short-term mobility and longer-stay vacationing. The average length of stay is approximately four days, with significant variation between coastal areas (over six days) and urban contexts (two to three days). This equilibrium reflects the coexistence of both stopover and destination tourism within the same regional system.

Spatially, tourism in Friuli-Venezia Giulia displays a clear pattern of concentration. The coastal resorts of Lignano Sabbiadoro and Grado remain the pillars of seaside tourism, accounting together for more than 60% of total stays during the summer season. Trieste, conversely, has consolidated its position as an urban and cultural hub—an interface between Italy and Central-Eastern Europe—thanks to its historical cosmopolitan identity and growing role in cultural events and cruise tourism. The inland provinces of Udine and Pordenone, while registering lower absolute volumes, contribute to diversification through specialised segments such as industrial, trade fair, and nature-based tourism.

The above analysis of sociodemographic and tourism-related components was conducted based on the following sources:

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4.3. The Context of the UTE Naples

4.3.1 The Territory

Naples is located along the central stretch of the Tyrrhenian coast, within a vast volcanic and coastal basin that forms the heart of the metropolitan area. Bordered to the east by Mount Vesuvius and to the west by the Phlegraean Fields, the city occupies a complex territory shaped by overlapping geomorphological systems, steep slopes, and ancient craters. Its urban fabric extends across a succession of hills, coastal plains, and peri-urban plateaus, connecting with a dense constellation of neighbouring municipalities such as Pozzuoli, Quarto and Portici. This territorial configuration makes Naples a highly distinctive urban environment, where geological dynamics, historical settlement layers, and contemporary metropolitan expansion intersect to define its spatial identity.

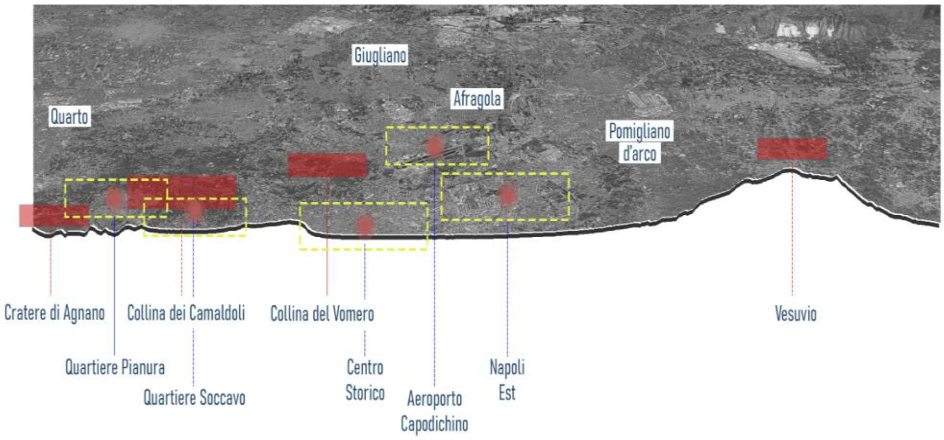

Figure 7: The municipal territory of Naples

As shown in Figure 7, the municipal territory of Naples is situated within a broader metropolitan cross-section that highlights both its geomorphological structure and its relationship with the surrounding urban systems. The image displays the sequence of volcanic craters, ridges, and hill systems—such as the Agnano crater, the Camaldoli ridge, and the Vomero hill—that define the city's topographic profile and strongly influence its settlement patterns. To the north, the figure positions Naples in relation to the municipalities of Quarto, Giugliano, Afragola, and Pomigliano d'Arco, illustrating the continuity of the built fabric across administrative boundaries and the progressive flattening of the terrain toward the inland plain.To the east, the image extends toward the Vesuvius system, whose morphological prominence emerges clearly along the metropolitan axis.

Overall, Figure 1 provides an integrated territorial perspective, situating Naples within a complex volcanic and urban landscape where morphological structures, historical craters, and neighbouring municipalities intersect to shape spatial dynamics and environmental vulnerabilities

Focus on the Ninth Municipality

The Ninth Municipality of Naples includes the districts of Soccavo and Pianura; it is located in the western periphery of the city, in an area lying between the hilly reliefs of the Camaldoli and the volcanic system of the Phlegraean Fields (Figure 8).

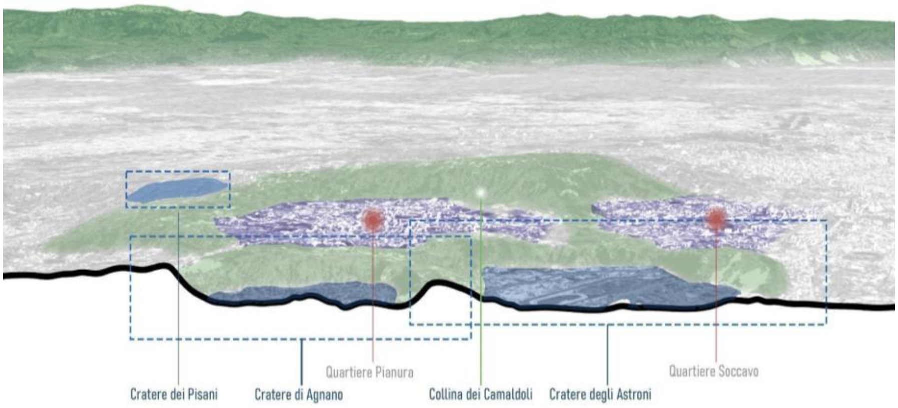

Figure 8: Morphology of the area

Figure 9: Soccavo and Pianura in the late XIXth Century, before the urbanisation process

The analysis of territorial characteristics was carried out through an integrated approach combining institutional data sources, advanced GIS tools, and spatial-processing procedures aimed at reconstructing the socio-morphological structure of the territory at a sub-municipal scale. Specifically, the information framework was built from ministerial, regional, metropolitan, and municipal datasets, digital elevation models, and ISTAT census data, subsequently harmonized and processed through extraction, interpolation, and statistical aggregation operations. This integration made it possible to coherently model both the building morphology and the estimated population distribution, using the single building as the minimum territorial reference unit.

The evolution of the urban fabric of Naples' Ninth Municipality reflects the progressive transformation of a historically peripheral area into a densely built-up district, through phases of intense and often unplanned building expansion. The cartographic reconstruction of the built environment from 1936 to 2024—based on WMS services from the Military Geographic Institute, the Campania Region, and the Metropolitan City of Naples—allows the historical evolution of the urban fabric to be read in sequence (Figure 10).

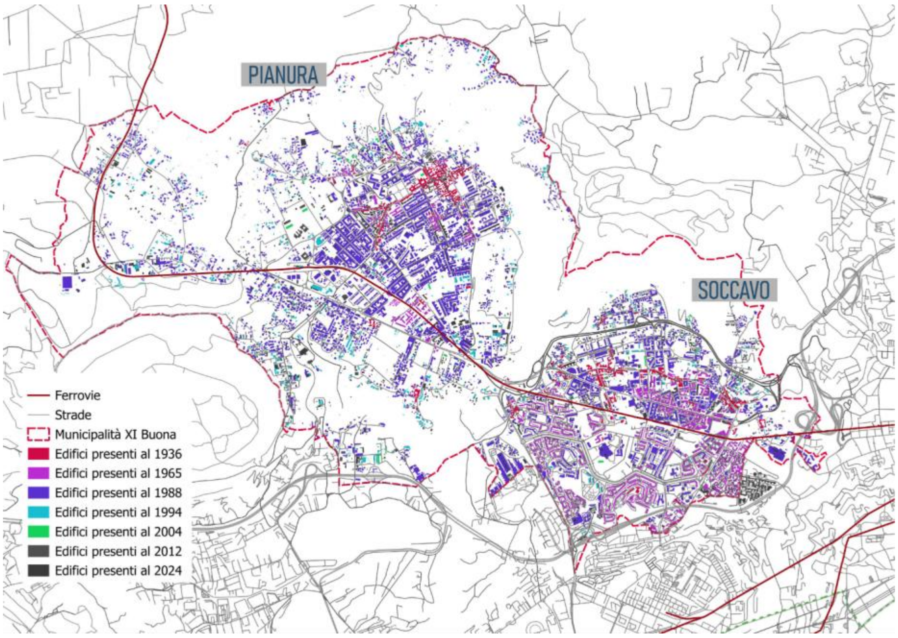

Figure 10: Historical evolution of the built environment of IX Municipality

The two districts developed independently until 4 July 1926, when they were annexed to the Municipality of Naples. Until the 1950s, Soccavo and Pianura experienced limited and compact growth around their historic cores, with functions closely linked to agriculture. Starting in the 1960s, building expansion accelerated, with the city progressively extending westward and northwestward. During this phase, Pianura experienced widespread, fragmented, and unregulated growth, facilitated by weak urban planning controls (Attademo et al., 2021). In Soccavo, by contrast, construction began on the INA-Casa housing district of Rione Traiano.

During the 1980s, following the 1980 earthquake, the Ninth Municipality underwent its most intense phase of building expansion. Extraordinary reconstruction programs and emergency housing policies led to a significant increase in public residential construction in the city's peripheral areas, including Soccavo and Pianura. In particular, Soccavo expanded by saturating the inner flat areas and extending toward the Camaldoli ridge, while Pianura was affected by multiple public-housing interventions—often irregular, informal and incomplete—that radically altered its urban morphology, introducing large, high-density building complexes in its central zone. Conversely, in peripheral and marginal areas, extensive development prevailed, characterized by single-family dwellings and a more dispersed settlement pattern. This situation was exacerbated by the absence of effective planning instruments capable of regulating urban growth, producing a heterogeneous settlement morphology marked by strong discontinuities.

Between the 1990s and the 2000s, growth consolidated: urbanization mainly affected marginal areas, progressively saturating residual spaces. Soccavo acquired a compact, high-density configuration, while Pianura continued to expand in a scattered and discontinuous pattern, characterized by extensive urbanization and frequent shortages of infrastructure and local services.
The most recent phase, between 2000 and 2024, shows a slowdown in expansion processes and a consolidation of the existing built environment, with targeted infill interventions in partially vacant areas.
However, this saturation has not been accompanied by parallel infrastructural development, accentuating the functional imbalances and structural deficiencies that still characterize the municipal territory.
A historical reading of the evolution of the built fabric thus reveals a model of rapid, fragmented, and weakly planned growth. This process has produced a significant increase in building density, with major implications for hydrogeological and environmental risk management.
The Municipality is crossed by a complex yet uneven infrastructural network. The railway axis of the Cumana line constitutes the backbone of local mobility, connecting the Pisani (Naples), Pianura, Trencia, Traiano, Soccavo, and Piave (Naples) stations with both the city center and the Phlegraean area. Although it represents a key infrastructure, it mainly functions as an external-connection corridor. Public road transport, instead, is managed by the municipal company ANM. The road network is organized around two main routes: the Soccavo–Pianura penetration axis, which crosses the volcanic plain, and the connections to the Naples ring road (Tangenziale), accessible from the junctions of Via Epomeo and Via Montagna Spaccata. However, the secondary road network is fragmented and lacks hierarchy, generating congestion in dense sections and isolation along peripheral margins.
The morphology of the territory strongly constrains mobility organization: the Camaldoli ridge and the volcanic basins of the Phlegraean Fields impose obligatory routes and limit transversal connections. Tunnels and viaducts help overcome physical barriers but often accentuate urban fragmentation, acting more as separators than connectors.
To deepen the understanding of the built environment in the Ninth Municipality, an advanced analysis was conducted to reconstruct morphometric and demographic parameters at the building scale[1].

4.3.3 The socio-economic and demographic context

[1] Building height was estimated by comparing the Digital Surface Model (DSM) and the Digital Terrain Model (DTM), deriving a normalized Digital Surface Model (nDSM). For each building polygon, the mean value of nDSM within its boundaries was extracted, obtaining an estimate consistent with urban morphology and the elevation-data resolution. The average floor height was assumed to be 3.20 m, allowing the estimation of the number of floors as follows:
Ni=round(Hi/3,20)
where
Hi represents the average height of the i-th building.
The building volume was estimated as the product of base area and average height:
$Vi = Af,i \times Hi$
where:
• Af,i = base area of the i-th building [m²]
• Hi = average height derived from nDSM [m]
A flat roof was assumed, and no volumetric correction coefficients were applied, in line with the exploratory and comparative purpose of the analysis.

In the Metropolitan City of Naples (that was established on 1 January 2015 and contains 92 towns, with Naples as capital) between 2001 and 2024 there has been a long-term pattern of relative stability in population followed by a marked and continuous decline (Figure 11).

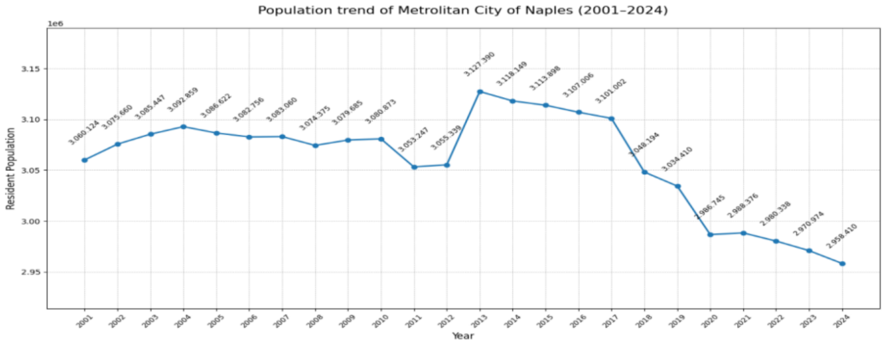

Figure 11: Population trend of Metropolitan City of Naples (2001-2024)

Source: <u>Tuttitalia.it</u>

In the early 2000s, the population remained consistently above 3.06 million residents, reaching a modest peak in 2004–2005. A notable shift occurred around 2012–2013, where there was an increase, bringing the population to over 3.12 million residents. From 2014 onwards, the population began a slow but steady decline, which accelerated significantly after 2017. The most critical phase began after 2019, when the population dropped below 3 million residents, marking a symbolic threshold for the metropolitan area. The trend continues progressively until 2024, when the population reaches its lowest point in the time series (2.958.410), representing a contraction of roughly 120,000 residents compared to the 2013 peak.

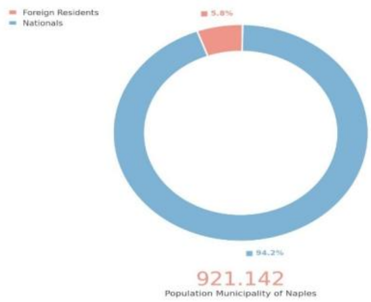

Figure 12: Total Resident population vs. Foreign Residents in Naples 2021

Source: Parliamentary Commission of Inquiry into Urban Safety Conditions and the State of Decay of Cities and Their Suburbs, 2021; ISTAT.

According to the data, in 2021, the total population residing in the city of Naples was 921.142 people (of whom 53,440 were foreign residents). This distribution highlights that foreign residents account for only a small fraction of the total (5,8%) (Figure 12).

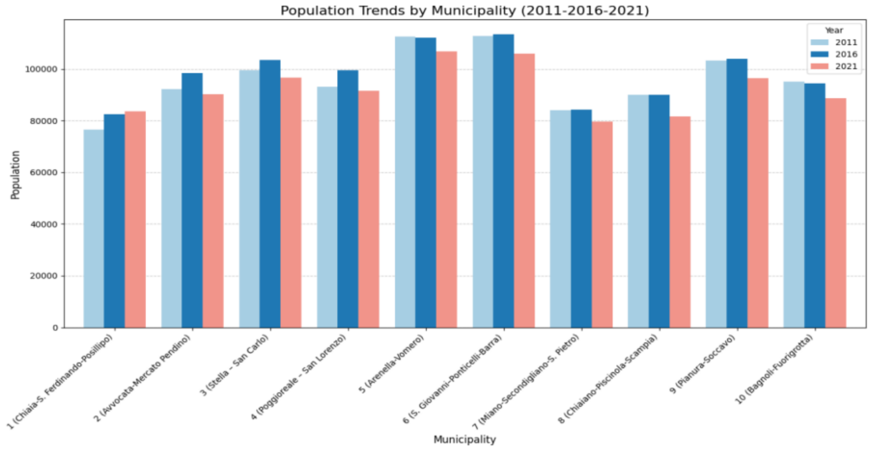

Figure 13: Population trends by Municipality of Naples (2011-2021)

Source: Fonte: Censimento ISTAT 2011 e 2021. Servizio Statistica comune di Napoli, 2016.

The population trends across the ten Municipalities of Naples between 2011 and 2021 reveal a pattern of widespread demographic contraction, albeit with varying intensities across the urban territory (Figure 13). The comparative view of 2011, 2016 and 2021 data shows that no municipality (except for Chiaia-S. Ferdinando-Posillipo) recorded an overall population increase over the decade, confirming a citywide decline.

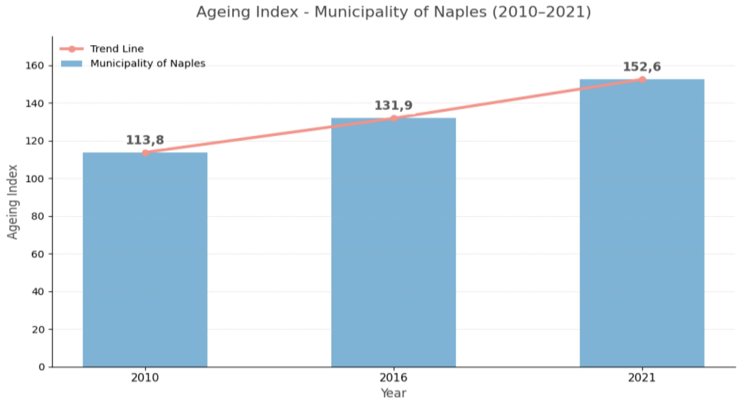

Figure 14: Ageing index - Municipality of Naples

Source: La struttura demografica della popolazione nella città di Napoli, 2016; ISTAT Census 2021.

The ageing index trajectory (Figure 14) points to a municipality undergoing advanced demographic ageing, with foreseeable consequences for urban planning, social policy, and community resilience.

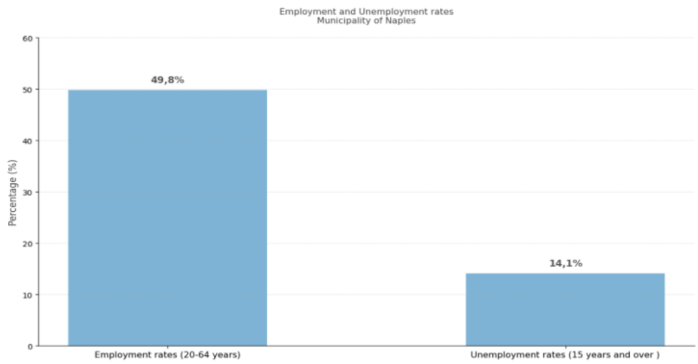

Figure 15: Employment and unemployment rates - Municipality of Naples

Source: Parliamentary Commission of Inquiry into Urban Safety Conditions and the State of Decay of Cities and Their Suburbs, 2021; ISTAT.

Figure 15 illustrates employment and unemployment rates in the Municipality of Naples in 2021. The employment rate for individuals aged 20–64 is 49.8%, representing roughly half of the working-age population. The unemployment rate, measured for residents aged 15 and over, stands at 14.1%.

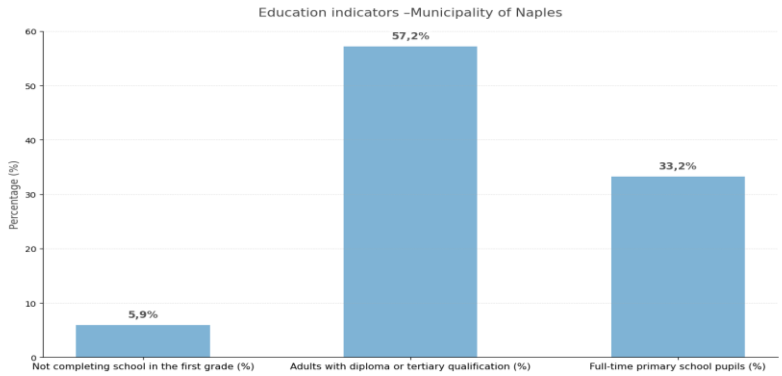

Figure 16: Education indicators - Municipality of Naples 2021

Source: Parliamentary Commission of Inquiry into Urban Safety Conditions and the State of Decay of Cities and Their Suburbs, 2021; ISTAT.

As for education (Figure 16), data reveals that the share of people not completing school in the first grade is 5.9%. Adults holding a diploma or tertiary qualification represent the largest group, corresponding to 57.2% of the population. The percentage of full-time primary school pupils is 33.2%.

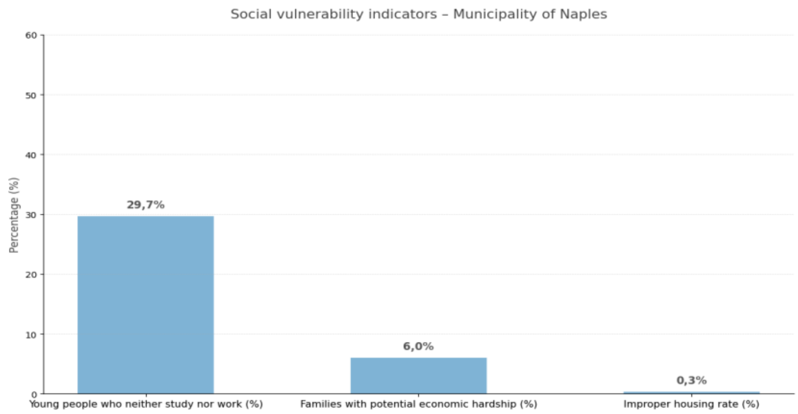

Figure 17: Social vulnerability indicators (1) - Municipality of Naples 2021

Source: Parliamentary Commission of Inquiry into Urban Safety Conditions and the State of Decay of Cities and Their Suburbs, 2021; ISTAT.

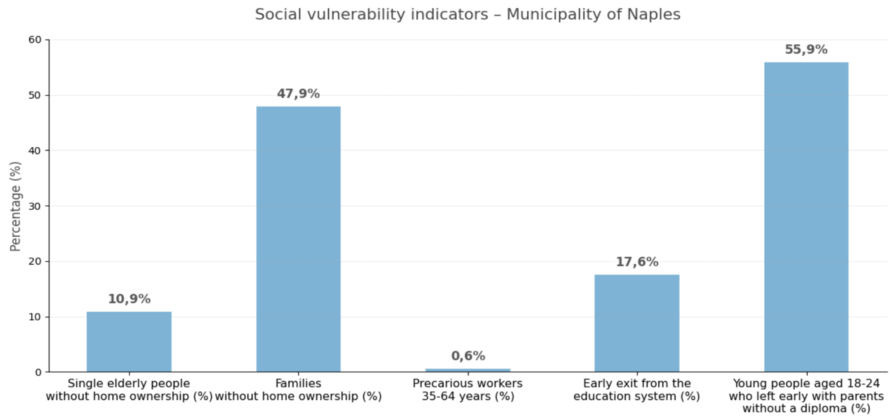

Figure 18: Social vulnerability indicators (2) - Municipality of Naples 2021

Source: Parliamentary Commission of Inquiry into Urban Safety Conditions and the State of Decay of Cities and Their Suburbs, 2021; ISTAT.

The indicators about social vulnerability (Figures 17 and 18) outline several critical elements.
A first crucial factor concerns that 55.9% of young people aged 18–24 who left education early come from families where parents do not hold a diploma, underscoring the persistence of intergenerational disadvantages, while 17.6% of individuals have exited the education system prematurely. In addition, there is a high percentage of young people who neither study nor work (29.7%), signaling a substantial segment of the youth population experiencing educational disengagement and limited integration into the labour market.
Additional indicators reveal further kinds of vulnerability: 6% of families face potential economic hardship. Taken together, these data depict a city where educational disadvantages, youth marginalisation, and housing insecurity represent the most prominent vulnerabilities.

Talking about Naples, it is important to also underscore its centrality in tourism. According to data, Campania ranks as the first region in Southern Italy in terms of tourist presence in 2025, and within this regional framework, the city of Naples stands out for its high growth rate recorded in the 2024–2025 period (SRM, 2025).

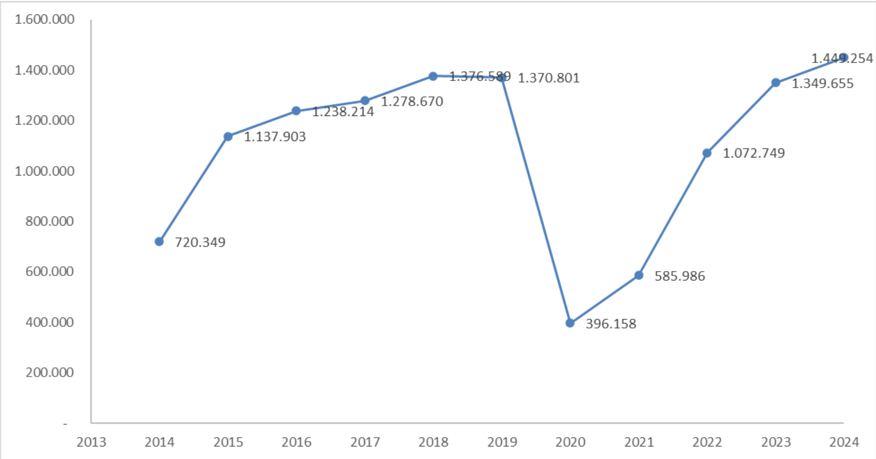

Figure 19: Tourist presences in Naples

Source: Occupancy of tourist accommodation establishments by type of accomodation and residence of the guests (ISTAT 2014-2024)

The analysis of tourism presences over the last decade shows clear evidence of steady expansion, interrupted only by the pandemic shock of 2020 (Figure 19). Between 2014 and 2019, tourist presences increased from 720,349 to over 1.37 million, marking a substantial growth phase characterised by the internationalisation of demand and the consolidation of the city as a European city-break destination, for its historical, cultural, and landscape characteristics. The collapse registered in 2020 (396,158 presences) reflects the impact of COVID-19 on global mobility, yet Naples rapidly recovered in the following years: presences more than doubled in 2021 (585,986) and exceeded one million again in 2022 (1,072,749). The strongest acceleration occurred between 2022 and 2024, when presences rose first to 1.349.655 (2023) and then to 1.449.254 (2024). The 2024 value not only surpasses pre-pandemic levels but also marks the highest volume of tourist presences ever recorded in the city in the last 10 years.

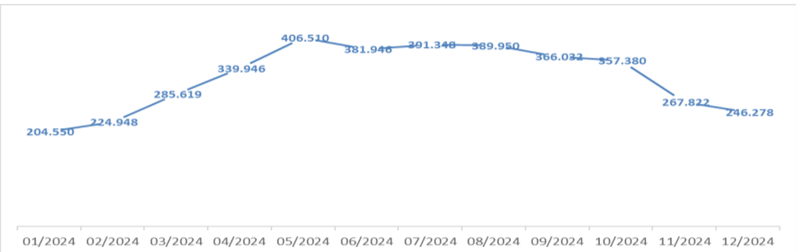

Figure 20: Distribution of tourist flows throughout 2024 in Naples

Source: Nights spent in tourist accommodation establishments by municipality - Monthly data 2022-2024 (ISTAT 2024)

With regard to the distribution of tourist flows throughout the year, it is important to note that the 2024 data show a steady rise in arrivals from January to late spring (Figure 20). Visitor numbers increased from 204,550 in January to 406,510 in May, reflecting the city's growing attractiveness during the spring months, a period traditionally favourable for cultural and urban tourism. High levels are maintained during the summer: June (381,946), July (391,348) and August (389,950) display remarkable stability, confirming Naples' ability to attract tourists beyond the typical city-break season. September still records very high volumes (366,032), while October (357,380) marks a further but moderate decline, remaining substantially above winter values. A sharper decrease is observed in November (267,822) and December (246,278), consistent with the general slowdown of urban tourism in colder months.

The extended tourism season, with a relatively balanced distribution of flows across spring, summer and early autumn, implies that the city hosts a mobile and constantly renewed population for most of the year. This continuous influx creates a scenario in which risk management cannot be designed solely around the resident population. Instead, authorities must operate under the assumption that large numbers of non-resident individuals are present almost continuously. This condition increases the need for mechanisms and procedures not only for residents but also for those of people who may be unfamiliar with local infrastructures, mobility systems, and emergency protocols.

Focus on the Ninth Municipality

With a total surface area of 16.5 km² and a resident population of over 100,000 inhabitants, the Ninth Municipality is one of the largest and most densely populated administrative units of Naples. The area borders the municipalities of Marano and Quarto to the north and the municipality of Pozzuoli to the west. On its eastern side, it interfaces with three other city municipalities: the Eighth (Chiaiano, Piscinola, Scampia) to the northeast, the Fifth (Vomero, Arenella) to the east, and the Tenth (Bagnoli, Fuorigrotta) to the south.

The classification of land uses (Figure 21) highlights a strong residential component, which overwhelmingly defines the character of both districts and represents their dominant function. This residential function is complemented by productive areas, public services, and commercial activities, although these are not evenly distributed between the two neighborhoods.

In particular, Soccavo presents a more compact and continuous functional structure, with higher residential density and a broader range of public and community services. Commercial activities are mainly concentrated along the Via Epomeo axis, while schools and public facilities are more evenly distributed throughout the area. In the district of Pianura, residential use also predominates but is spread in an extensive and unplanned manner. Commercial and public services are mostly concentrated within the compact fabric of the historic center. Moving toward the peripheral and hilly areas, the functional structure becomes increasingly fragmented, giving way to small industrial clusters.

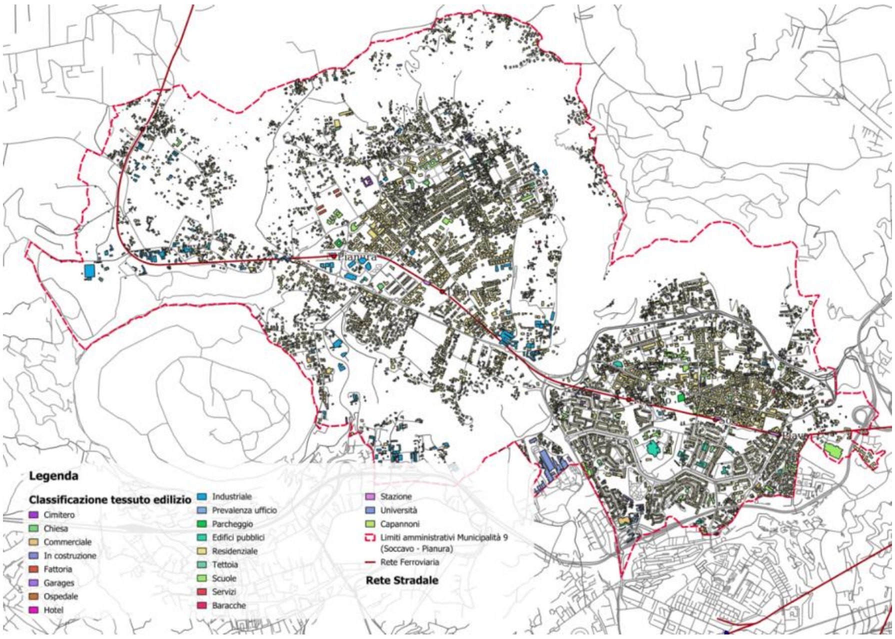

Figure 21: Functional and typological distribution of the built environment

As for the resident population, the number of inhabitants is relatively limited between the late 19th century and the post–Second World War period (Figure 22). After the war, however, within approximately thirty years, the two districts' population rose to over 100,000 inhabitants, following distinct trajectories.

On the one hand, Soccavo experienced particularly intense growth between 1961 and 1971, reaching its historical peak in 1981 with 61,762 residents. It then entered a phase of steady decline: by 2021, the population had fallen below 40,000. Pianura, on the other hand, continued to attract new residents until the early 2000s, reaching a peak of 58,362 inhabitants in 2001. The former rural village thus transformed into a true urban district, with an increase of roughly forty thousand inhabitants in three decades. Since 2001, Pianura has also reversed its demographic curve, entering a phase of gradual population loss similar to that already observed in Soccavo. The demographic contraction of the past twenty years reflects a broader phenomenon affecting Naples and many southern Italian cities: declining birth rates, shrinking family size, and outward migration toward the metropolitan belt or other regions (Di Gennaro, 2019).

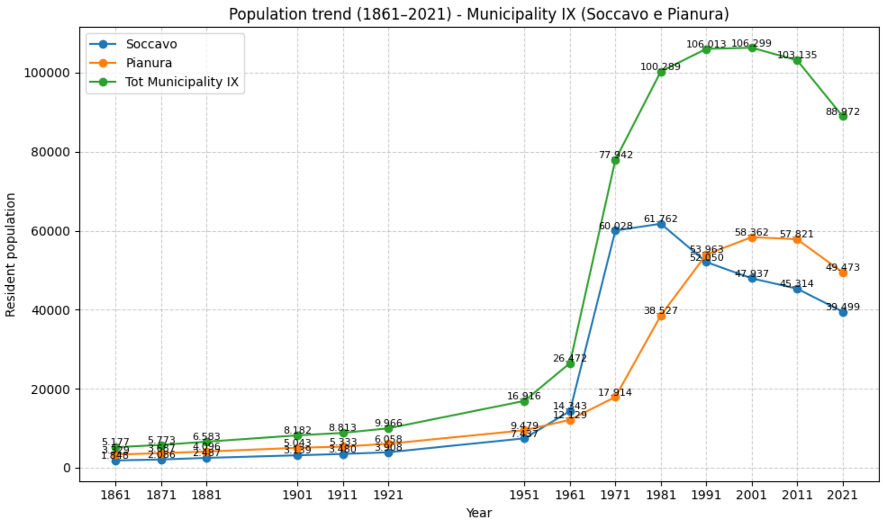

Figure 22: Population trend

Source: Comune di Napoli, Servizio Studi Demografici ed Economici; Istituto Centrale di Statistica (1960); ISTAT Censuses 2011 and 2021.

As for the population density (Figure 23), between 2001 and 2021 a gradual decline can be observed both at the municipal and neighborhood scales, marking the end of the phase of maximum building and demographic saturation. In 2001, the Municipality recorded a density of over 14,500 inhabitants per km², already a very high value in metropolitan terms. The following decade showed a moderate contraction, followed by a sharper decrease between 2011 and 2021, to about 12,000 inhabitants per km². The decline is also visible at the neighborhood level, albeit with different levels and rates: Soccavo dropped from roughly 9,300 to fewer than 7,800 inhabitants per km², while Pianura—traditionally less dense due to its hilly and peri-urban morphology—decreased from about 5,100 to just over 4,300 inhabitants per km².

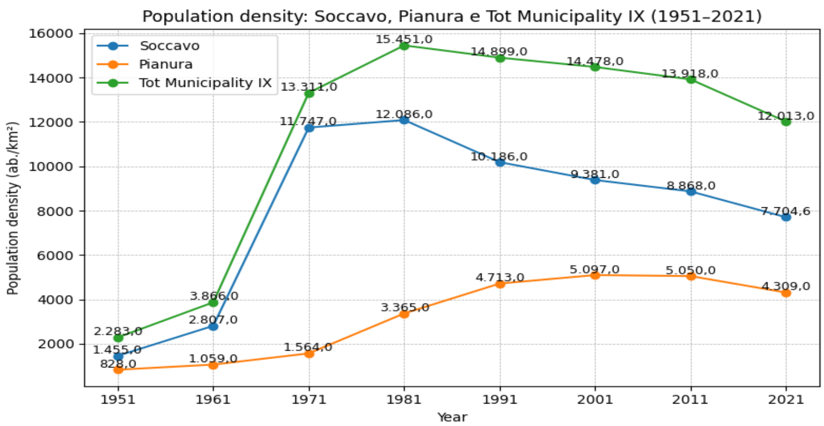

Figure 23: Population density

Source: ISTAT Census 2021.

In a subsequent phase, an estimation of the resident population per building was also carried out (Figure 24)[2]. In the district of Pianura, buildings with the highest residential density are concentrated along the central axis and around the historic urban core, where the compact building fabric and the prevalence of multi-storey structures generate high values of population per building. Moving westward and northward, density progressively decreases.

In Soccavo, by contrast, the concentration of densely inhabited buildings is broader and more continuous. The highest values are recorded in the heart of the district and in the Rione Traiano area, where large residential complexes, public housing estates, and high-rise condominium buildings produce significant demographic density. Toward the northern and eastern edges, near the hilly slopes, density gradually decreases, giving rise to a less compact residential landscape.

Field observations revealed that a significant portion of the residential fabric—particularly in Pianura—has developed through informal and unauthorized construction processes that intensified after the 1980 earthquake. This widespread expansion of illegal building has had direct consequences on the provision of public services and urban standards, contributing to a fragmented urban structure often lacking adequate collective facilities.

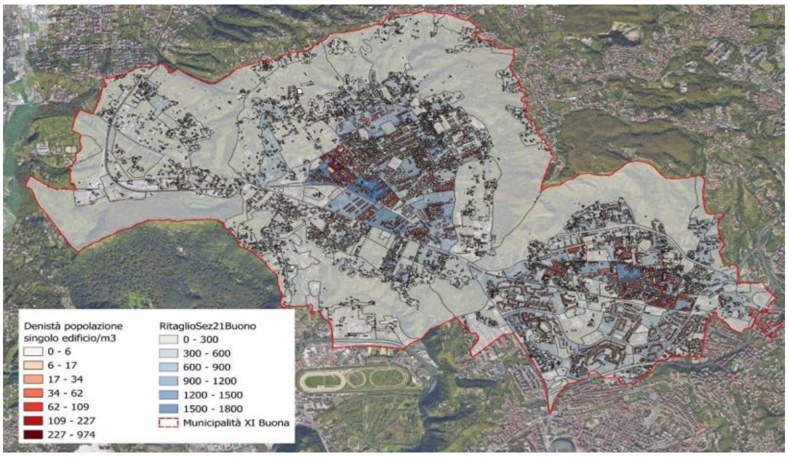

Figure 24: Density of resident population per building

Alongside this diffuse informal expansion, both Pianura and Soccavo host large public housing estates. In particular, in Pianura are located the Rione Cannavino and Case Gialle neighborhood while in Soccavo are located in the area of Via Palazziello and the extensive Rione Traiano. Within these areas, the presence of unauthorized occupants and precarious housing conditions is frequent, with inhabitants living in substandard dwellings that remain largely invisible in official statistics.

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[2] The estimation was made possible through a proportional redistribution procedure of ISTAT census data, whereby the population of each census section was allocated to residential buildings in proportion to their volume, ensuring consistency between official demographic data and the physical structure of the built environment.

$$POPi = POPs \times (Vi / \sum j \in RsVj)$$

where:

- POPi= estimated population for building *i*,
- POPs= total population of the census section,
- Vi= volume of building *i*,
- ∑Vres= sum of the volumes of all residential buildings within the same census section.

Social profile

To obtain a comprehensive picture of the socio-economic context, several dimensions were considered. The first economic indicator analyzed was the employment rate (Figure 25), alongside the unemployment rate (for individuals aged 15 and over). The graph highlights moderate yet significant differences between Soccavo and Pianura, reflecting the distinct social and demographic structures of the two districts. Soccavo records an employment rate of 49.1%, higher than that of Pianura (46.1%). Conversely, the unemployment rate is higher in Pianura (16.1%) than in Soccavo (14.5%).

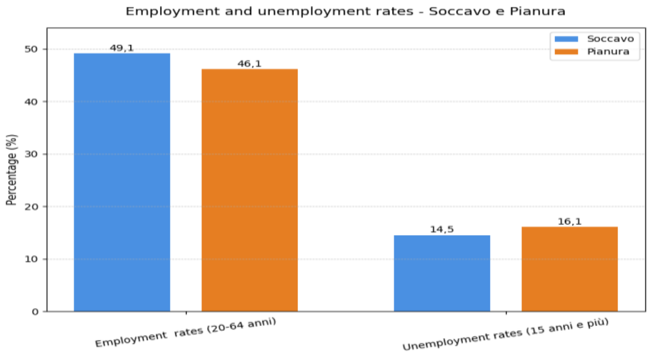

Figure 25: Employment and unemployment rates - Soccavo e Pianura

Source: Parliamentary Commission of Inquiry into Urban Safety Conditions and the State of Decay of Cities and Their Suburbs, 2021; ISTAT.

As regards education (Figure 26), both districts show levels of educational attainment below the national average, reflecting the fragile educational conditions typical of many southern urban peripheries—albeit with differing intensity.

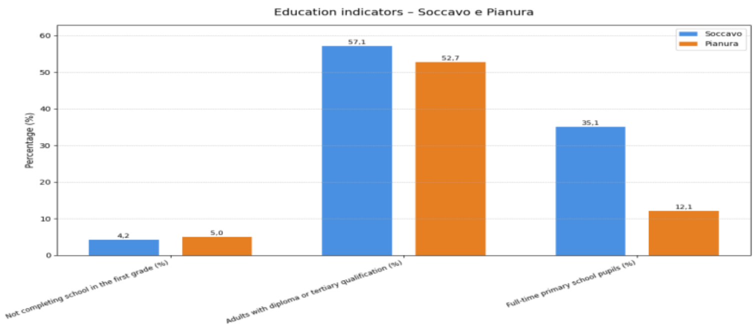

Figure 26: Education indicators

Source: Parliamentary Commission of Inquiry into Urban Safety Conditions and the State of Decay of Cities and Their Suburbs, 2021; ISTAT.

The trend of the ageing index (Figure 27) in the Ninth Municipality reveals a marked and progressive ageing of the population in both Soccavo and Pianura. In 2010, the two districts displayed very different levels: Soccavo recorded an index of 123.68, already above the city average, whereas Pianura stood at a much lower value (60.64), reflecting a traditionally younger demographic structure. In the following decade, however, both districts experienced a steady increase in the index—at different intensities but along the same trajectory. Soccavo reached 180.60 in 2021, showing a strong process of population ageing, the outcome of a long phase of urban saturation followed by gradual depopulation. Pianura, although starting from lower values, displayed an even faster increase, rising from 60.64 to 124.20 over the same period. The district of Pianura is therefore converging toward ageing levels similar to those of Soccavo and, more generally, to the citywide and national averages.

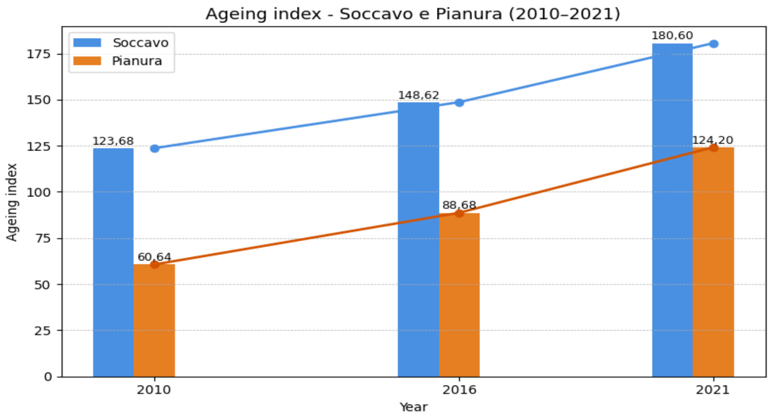

Figure 27: Ageing index

Source: La struttura demografica della popolazione nella città di Napoli, 2016; ISTAT Census 2021

A further indicator of the social composition of the Ninth Municipality concerns the presence of foreign residents (Figure 28). The data reveal a differentiated distribution between the two districts: Pianura registers a significantly higher presence, with 1,301 foreign residents (26.3% of the total), whereas Soccavo hosts 509 foreign residents, accounting for approximately 12.9% of the population. Although statistical sources do not register a substantial presence of foreign residents in Soccavo, during on-site fieldwork, researchers noted a small but significant enclave of migrant households settled in semi-basement and substandard units—locally referred to as *scantinati*.

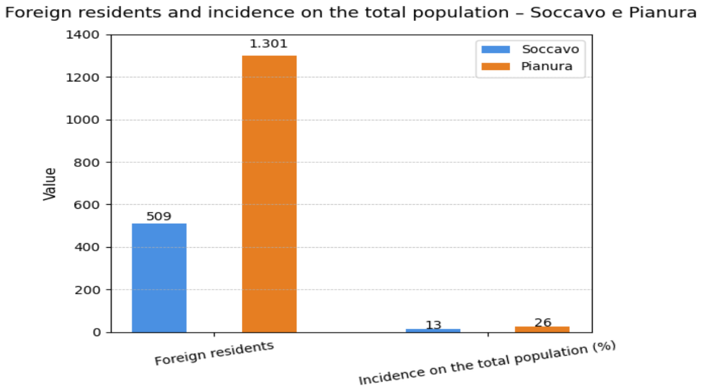

Figure 28: Foreign residents

Source: Commissione parlamentare di inchiesta sulle condizioni di sicurezza e sullo stato di degrado delle città e delle loro periferie, 2021, Istat.

The analysis of social vulnerability indicators (Figure 29 and 30) confirms the presence of widespread critical conditions across both districts of the Ninth Municipality, with slightly greater intensity in Pianura. The most relevant figure concerns the share of young people not in education, employment, or training (NEETs): 28.5% in Soccavo and 30% in Pianura. The share of families experiencing potential economic hardship reinforces this picture: Pianura registers 7.5%, compared with 5.6% in Soccavo.

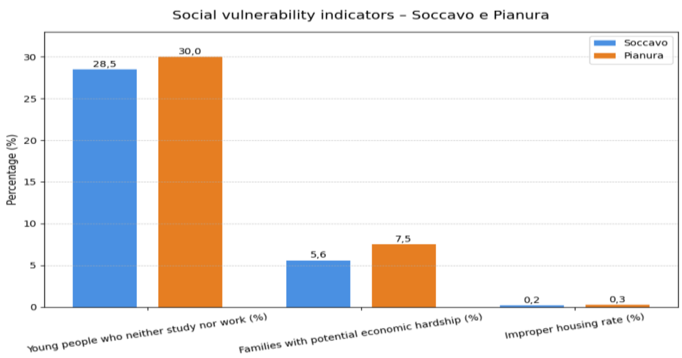

Figure 29: Social vulnerability indicators

Source: Parliamentary Commission of Inquiry into Urban Safety Conditions and the State of Decay of Cities and Their Suburbs, 2021; ISTAT.

Finally, the rate of inadequate housing highlights the persistence of housing precariousness, embedded in a territorial history marked by informal urbanization and irregular development patterns. The proportion of families without home ownership is high in both districts (43.8% in Soccavo and 46.5% in Pianura), indicating a structural condition of residential precariousness and a comparatively weaker household asset base relative to the national average.

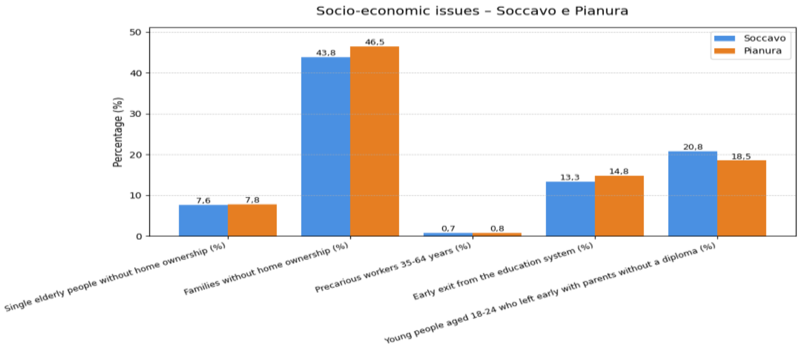

Figure 30: Socio-economic vulnerability

Source: Parliamentary Commission of Inquiry into Urban Safety Conditions and the State of Decay of Cities and Their Suburbs, 2021; ISTAT

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5. The Multi-Risk Scenarios in the UTEs

5.1 The Multi-Risk Scenarios in the Genoa UTE

The results presented in this paragraph contribute to the definition of an updated picture of natural risk in Genoa, based on the analysis of traumatic events that occurred in an intermediate time window (approximately 15–25 years), the damage and losses resulting from them, the scientific literature that has investigated their causes and impacts – largely produced by scholars at the University of Genoa – and the prevention and mitigation policies implemented by the municipality and other local actors. The joint observation of these elements provides a clear, albeit mainly qualitative, reading of the city's degree of exposure and vulnerability to the main natural hazards.

Over the last fifty years, Genoa has been hit by twelve serious floods, causing numerous casualties and extensive damage to public and private property. This frequent exposure is primarily due to natural factors: the city's particular orographic and coastal morphology favours the meeting of warm and cold air masses and the formation of self-regenerating storms, responsible for extremely intense and localised rainfall. Over the last two decades, climate change has accentuated this dynamic, making these phenomena more frequent and violent, and often concentrated in small areas — the so-called "water bombs". Scientific records from the regional meteorological services now show peaks of over 300 mm of rain in a few hours in some districts of the city — values previously considered exceptional but increasingly recurrent.

However, the rainfall encounters a highly vulnerable territory, where physical conditions and socio-economic factors intertwine. Floods, which are not an autonomous hazard but the effect of complex meteorological and geomorphological processes, are aggravated by the presence of watercourses channelled or buried in the urban fabric. Genoa has about 150 rivers, many of which flow in underground or artificial conduits, and two main torrents — Bisagno and Polcevera — characterised by steep slopes and flow times of less than an hour. Added to this is historical anthropogenic pressure: the progressive urbanisation of riverbeds and floodplains has reduced natural flood spaces, while the abandonment of terraced agricultural slopes has decreased the capacity of hillsides to retain water. The result is a shortening of watershed concentration times and a rapid transition from rainfall to peak discharge. The floods of the Bisagno (2011 and 2014) and Fereggiano (2011) rivers remain among the most emblematic examples of this interaction between physical vulnerability and deficient land management, and were followed by complex and costly mitigation measures — including riverbed enlargement, the reconstruction of bridges, and the construction of the Bisagno diversion tunnel — whose completion times extend over decades.

A second, rapidly growing risk factor is heat waves. In an urban context in northern Italy, especially on the coast, such exposure may seem counterintuitive. However, the increase in average air and sea temperatures has reduced the daily temperature range and weakened the cooling effect of the sea breeze. In an environment already characterised by high humidity, this generates "silent" heat waves, often not detected by alert protocols but with a high health and social impact. Recent health and social services data indicate that the most affected groups are elderly people who are alone and in difficult economic conditions, living in poorly ventilated homes or without adequate air conditioning, often located in densely built-up neighbourhoods with little greenery and weak social cohesion. Unlike flood risk, heat risk is less structured in monitoring and prevention systems: official recognition by the municipal Civil Protection Department has now been achieved, but there is a lack of systematic data correlating extreme temperatures with hospital admissions and mortality, and public policies remain sporadic. Seasonal communication campaigns and volunteer-based support networks exist, but there is no structural "heatwave plan" comparable in scope and coordination to flood-related procedures.

Finally, a third form of exposure concerns storm surges and strong winds, events that are less frequent but potentially devastating for coastal areas. The geomorphological characteristics of the Genoese coastline — squeezed between the sea and the mountains — amplify the impact of exceptionally severe storm surges, which can damage port, coastal and residential infrastructure. The storm surge of October 2018, which devastated Nervi, Quinto and the coastal strip up to Voltri, remains the most dramatic event, destroying promenades, seawalls and dozens of commercial activities. Even events such as Storm Vaia (2018), although only marginally affecting Liguria, highlighted the vulnerability of the area to extreme wind events, with falling trees, widespread blackouts and damage to roofs and public infrastructure.
Although less frequent than floods and heatwaves, these events pose specific challenges: the protection of critical coastal infrastructure, the adaptation of the port system — one of Italy's largest — and the integrated management of marine and atmospheric risk. In recent years, the Municipality and the Region have launched initiatives to reinforce coastal defences, update the Civil Protection Plan and participate in European projects on urban climate-proofing (including actions under Horizon Europe and Interreg), but there is a clear need for a comprehensive climate resilience strategy that integrates all natural hazards — fluvial, pluvial, marine and thermal — into a single territorial framework, and that considers physical exposure together with social vulnerability

5.1.1 Historical Review of Main Events Occurred

In this section, we reconstruct the main traumatic events related to natural phenomena that have occurred in Genoa with the aim of representing the city's exposure to natural risks.

In Table 3 the RETURN/Cure team has compiled a database consisting of data from institutional websites (Ispra, Liguria Region, Civil Protection, Arpal, Alisa), databases created by associations (Città Clima di Legambiente, Eco Istituto ReGe) and the archives of locally active media (mainly Il Secolo XIX, Genova Quotidiana; Genova 24 and Primo Canale). We went back 15 years: even in this time frame, it is clear that the Genoa area has been hit by a large number of catastrophic events of varying magnitude and nature, although mainly related to hydrogeological risk (and in particular, flooding of urban waterways). The range of such events widens further if we also take into account the decades following 1970, the year of the flood that caused the greatest loss of life and damage in the city between the 20TH and 21ST centuries.

In this section, we will present a brief account of these events. Where necessary, we will try to add some additional information gathered during the field research phase.

Since 1970, there have been numerous floods affecting large areas of the city and even more numerous localised floods. At approximately twenty-year intervals, successive floods have caused casualties and extensive material damage (October 1970, September 1992, September 1993, October 2010, November 2011, October 2014). If the analysis were extended to neighbouring municipalities, the list of victims would unfortunately be even longer. The most affected areas of the city are the two large valleys of the Bisagno and Polcevera rivers, together with the valleys of their tributaries. The neighbourhoods crossed by the Sturla, Varenna and Chiaravagna rivers have also suffered repeated and dramatic episodes. Between 2010 and 2025, these major incidents were compounded by dozens of minor incidents in which, following heavy rainfall, localised areas and specific road structures, such as underpasses, were repeatedly flooded.

Our list clearly shows that, over the last 50 years, heavy rainfall in the autumn months has been a trigger for floods, flooding and landslides. From the same list, it seems reasonable to assume that, at least since 2013, summer rains have also begun to be accompanied by flooding and other damage, particularly related to strong winds or 'tornadoes' (falling trees, damage to buildings and infrastructure, disruption to rail and road networks, etc.). Furthermore, since 2020, the sources consulted also show traces of such events in the spring and early summer months (March, April, May and June). In some cases, these events are preceded by periods of very high temperatures, thus falling into the *downburst* category.

With regard to extreme heat and phenomena known as 'heatwaves', Arpal's 'red alert' has become a fairly common occurrence. Heatwaves lasting more than eight days have occurred in almost every summer since 2003, although in terms of frequency, duration and impact, those of 2018, 2022 and 2023 have been particularly severe in recent years. In 2025, two heatwaves hit the city hard: one between June and July, with an 'early' and unexpected phenomenon. The other in the first half of August, with over 10 days of temperatures above the seasonal average.

However, climate data shows that previously unthinkable temperatures (above 38 degrees) are beginning to be recorded in the city several times during the summer season. This data, combined with humidity levels, which are traditionally very high in Genoa in summer, makes the Heat Index extremely dangerous.

During the summer of 2025, especially between the end of June and the beginning of July, in conjunction with this alarm, there are also reports in the newspapers of ill health among certain sections of the population, such as industrial workers, and malfunctions in technological equipment. Over the years, concerns about rising sea temperatures also seem to be increasing.

Another source of risk, especially for the health of urban dwellers, is air quality. Without going into detail about the measurements (which are complex, as they are carried out using various Arpal control units and popular monitoring projects for fine and ultrafine particulate matter and port fumes), associations working on these issues have noted for at least a decade that maximum values for various elements (such as nitrogen dioxide, ozone, and fine and ultrafine particulate matter) have been exceeded for prolonged periods (especially in summer). The associations' work also aims to highlight the greater exposure suffered by certain hillside neighbourhoods located behind some port areas (e.g. San Teodoro).

In October 2018 and January and September 2023, severe sea storms hit the Ligurian and Genoese coasts. These events caused enormous damage, given the concentration of buildings and infrastructure on the coast. Echoing the testimonies collected for this research, it is clear that storm surges are an emerging risk, both in terms of their impact and the concerns they raise among social actors.

The underlying theme of the list of catastrophic events in the Genoa area is the very high number of landslides and mudslides that regularly occur in urban, peri-urban and coastal areas. The cases of these events, the number of which is difficult to establish with certainty[3] , include landslides, with significant detachments of earth and rock (e.g. the Capolungo landslide in 2014), landslides and mudslides due to soil water saturation (e.g. the Panigaro quarry landslide during the October 2010 flood, in which a worker lost his life) and the collapse of retaining walls supporting the foundations of buildings and roads. Given the urban layout, the latter type of collapse is particularly frequent and affects structures dating back to different periods, from the 19TH century onwards. Landslides and mudslides cause frequent material damage and evacuations. Furthermore, when they interrupt the road network, they can cause the isolation of buildings, blocks or entire hamlets.

[3] The ISPRA portal that records major landslides and mudslides

(https://idrogeo.isprambiente.it/app/iffi?@=44.46400882855255,8.889615793873215,10) records approximately 1,300 'major incidents' in the Genoa area. As for minor incidents, consulting local newspapers can be useful, not so much to establish a count, but to ascertain the recurrence of such events and the extent of the damage and localised disruption they cause.

A final type of disaster that the Genoa area has proven to be susceptible to is industrial accidents. The port, which covers most of the city's seafront, and the industrial plants connected to it, represent a constant source of risk. Among these, the Iplom oil pipeline (the source of several spills, the last one in 2016) and the storage facilities for hydrocarbons and other flammable materials (in 1987, a fatal accident occurred in Multedo) have proven to be particularly dangerous. The incidence and intensification of extreme weather events is a major factor of uncertainty with regard to these risks.

Finally, although not environmental disasters, two tragic incidents caused by human error or negligence have had a profound impact on the first decades of the 21st century: the collapse of the Genoa port control tower, struck by the cargo ship Jolly Nero in 2013, and the collapse of the Polcevera viaduct – known as the Morandi bridge – in 2018.

Type	**Number of events**	**Links to sources for the most important events**
Floods, inundations	Approximately 25, 3 incidents caused casualties among the population	https://www.ilsecoloxix.it/genova/2010/10/05/news/alluvione-sospesele-ricerche-del-disperso-1.37998901 / https://www.genova24.it/2013/02/flood-sestri-ponente-judge-rejects-dismissal-of-case-for-death-of-paolo-marchini-swallowed-by-mud-in-panigaro-quarry-46520/ / https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A5131 https://servizio-nazionale.protezionecivile.gov.it/it/pagina-base/lalluvione-di-genova/#:~:text=On%20the%20night%20of%204%20November,east%20side%20of%20Val%20Polcevera. / https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A4119 https://it.wikipedia.org/wiki/Alluvione_di_Genova_del_9_e_10_ottobre_2014 / https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A4117
Landslides, mudslides	21 major events reviewed; the number of minor events is unknown	https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A4114 https://www.ilsecoloxix.it/genova/2015/02/26/news/borgoratti-e-capolungo-31-sfollati-in-attesa-da-anni-1.31661797/https://www.genovatoday.it/cronaca/lavori-frana-capolungo-regione.html https://www.genova24.it/2016/11/frana-via-portezza-un-centinaio-persone-sfollate-170406/ https://idrogeo.isprambiente.it/app/iffi/e/EIT201900147?@=44.387809841000006,9.0334428 59000074,21 https://idrogeo.isprambiente.it/app/iffi/e/EIT202200077?@=44.407466450773086,8.9861106 1155239,21;

		https://www.genovatoday.it/cronaca/frana-via-posalunga-sfollati.html https://www.genova24.it/2025/01/crolla-muro-a-lagaccio-la-frana-spezza-tubo-del-gas-zona-interdetta-intervento-in-corso-414190/
Storms, tornadoes	8 major events reviewed[*]	https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A4120 https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A4122 https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A4127 https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A4916 https://www.genova24.it/2025/07/grandine-genova-temporale-vento-downburst-allerta-432142/ / https://www.genova24.it/2025/07/grandine-genova-temporale-432279/
Extreme temperatures, heat waves	5 periods of major emergency	https://www.genova24.it/2019/01/meteo-il-2018-lanno-piu-caldo-in-liguria-dal-63-il-29-ottobre-una-raffica-da-180-km-h-la-piu-forte-mai-registrata-210667/ https://www.genovatoday.it/cronaca/morti-luglio-confronto-anni.html https://unigesostenibile.unige.it/agostorecord https://www.arpal.liguria.it/home-page/notizie-tematiche/item/temperature-eccezionali-liguria-2025-record-giugno.html https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A6212
Storm surges	3 major events	https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A5247 https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A5304 https://cittaclima.it/mappa/#data_s=id%3AdataSource_1-1832129bd57-layer-6%3A5607
Industrial accidents	1 event	https://genova.repubblica.it/cronaca/2016/04/17/news/cc-137852419/ / https://genova.erasuperba.it/sversamento-iplom-piano-di-emergenza-esterno-scaduto

Accidents caused by human acts or errors	4 major events	https://it.wikipedia.org/wiki/Tragedia_della_torre_dei_piloti_di_Genova https://it.wikipedia.org/wiki/Crollo_del_viadotto_Polcevera / https://genova.erasuperba.it/ponte-morandi-e-quellanno-zero-che-non-e-mai-arrivato-a-genova https://liguriaday.it/2022/09/12/bruciano-monte-moro-e-monte-fasce-lincendio-sempre-piu-grande-si-avvicina-alle-case/ https://www.ilsecoloxix.it/genova/2023/08/15/news/incendio_bosco_acquasanta_genova-12997272/

Table 3: Summary of events

[*] The events reviewed in this category are those in which wind is the main source of human and material damage. Tornadoes and strong winds are often associated with other events reviewed in the category 'Floods, inundations'.

5.1.2 Losses and Damage

The events described in the previous paragraph caused significant losses and damage to the city of Genoa.

In terms of losses, the most significant are those relating to human lives. The floods that hit Genoa in October and November 2010, 2011 and 2014 caused a total of nine deaths: two, six and one, respectively. However, the most dramatic human toll, but less recognised institutionally, seems to be that of heat waves. In 2003, a year that went down in history for its 'record' hot summer, more than 1,000 people died in the city between June and August, when the annual average for the previous five years was below 700 people. In subsequent years, summer mortality returned to pre-2003 levels, albeit with significant fluctuations between years (in 2018, there were 868 deaths, compared to 636 the following year). A detailed analysis of mortality and hospitalisations related to heat waves has not yet been carried out, although Alisa, thanks in particular to the contribution of Dr Ernesto Palummeri, has begun an analytical reconstruction with the support of the University of Genoa.

The damage to the city's housing and infrastructure, on the other hand, is more immediately reflected in the calculations made by the Municipality of Genoa and by private individuals who suffered damage and subsequently requested financial compensation from the State or the Liguria Region. This procedure was only possible for events that led to the declaration of a regional or national emergency, which, however, coincides with all the events reported in paragraph 2.1, with the exception of micro-landslides (tab.3).

State of Emergency	**Amounts (€) paid to implementing bodies in the Liguria Region**	**of which paid to implementing entities in the Municipality of Genoa**	**Link to dedicated web page**
October/November/December 2010 Floods	58,839,138.09	11,198,680.10	civil protection - year 2010 - Liguria Region

October-November 2011 Floods	83,378,115.74	6,197,146.77	civil protection - year 2011 - Liguria Region
December 2013 - January 2014 Floods	18,464,264.24	10,800.00	civil protection - year 2013-2014 - Liguria Region
October 2014 Flood	23,497,157.70	1,260,260.67	civil protection - year 2014 - October - Liguria Region
November 2014 Flood	51,451,970.30	1,916,635.37	civil protection - year 2014 - November - Liguria Region
September 2015 Flood	2,417,315.67	7,400.00	civil protection - year 2015 - Liguria Region
Storm Vaia - 28-29 October 2018	281,662,621.41	4,853,500.13	civil protection - year 2018 - 29 and 30 October 2018 - Liguria Region
Rain and gusts of wind October and November 2019	148,203,150.19	16,362,681.98	civil protection - year 2019 - events in October, November and December - Liguria Region
Total	667,913,733.34	41,807,105.02	

Table 4: Amounts paid to the Municipality of Genoa and the Region of Liguria for damage caused by natural hazards

Overall, approximately €42 million has been paid to implementing bodies (public and private) located in the Municipality of Genoa for damage caused by natural phenomena. The most serious damage to housing and public buildings was recorded during the repeated floods of the Polcevera and Bisagno rivers in 2010 and 2011, and due to Storm Vaia, which caused enormous damage throughout Liguria due to storm surges combined with heavy rain and strong winds.

As can be seen from the totals, the contributions awarded to the city of Genoa are substantial, but significantly 'below threshold' compared to those paid to the rest of the region, considering the number of inhabitants of the capital (approximately 35% of the region's total). The table 4 shows the figure of 668 million euros relating to events that affected both Genoa and the rest of Liguria. However, there have been extreme hydrogeological events that have affected the rest of the region but not Genoa (e.g. the floods of October and November 2016 and 2020, which mainly affected the Savona, La Spezia and Imperia areas), so the amount reported for the whole region is underestimated by approximately £80 million. This data shows that the municipality of Genoa, however fragile, is one of the most resilient agglomerations in the regional ecosystem and one of the most capable of preventing and mitigating damage from natural events, while the small municipalities in the Genoa metropolitan area and other provinces are much more exposed to catastrophic (and therefore costly) damage.

Furthermore, the damages that have been settled refer to both public and private property and have been subject to expert assessments and verifications by the disbursing bodies, in particular the Presidency of the Council of Ministers and the National Civil Protection Department. However, the amount of claims made, particularly by private individuals, is significantly higher than the amount paid out. If we refer only to events that occurred after 2014, private individuals submitted claims totalling approximately €215 million, but received only a tenth of that amount. This discrepancy is partly due to a lack of resources. However, interviews conducted with officials from the Liguria Region reveal that a significant proportion of claims remain unresolved due to documentation issues. This highlights the need to review policies on access to compensation, which risk producing a 'Matthew effect', whereby compensation is received by the part of the community that is already able to provide for itself.

5.1.3 Literature on Genoa's exposure and vulnerability to natural hazards

The review of empirical studies on Genoa was carried out by entering the keywords 'floods', 'landslides', 'Genoa', 'resilience' and 'disaster risk management/reduction' into the main academic search engines (WoS and Scopus). It was immediately apparent that most of the contributions, although often in English and published in international journals, came from authors affiliated with the University of Genoa or research organisations with roots in Liguria (e.g. CIMA). A second bibliographic search was therefore carried out using the IRIS-Unige search engine.

The searches were conducted in very different disciplinary fields: from geology to geography, from psychology to engineering. In particular, three clusters emerged:

- Literature analysing the causes of individual flooding episodes, through an analysis of the socio-ecological context of the city.
- Literature that focuses on the relationship between citizens and institutions, and cultural and communicative processes.
- Literature analysing technological prototypes and organisational experiments useful for anticipating future events and strengthening the preparedness of the local context.

In relation to the first strand, Genoa is a city particularly exposed to risk or flooding due to both anthropic and natural factors. Like other cities, Genoa grew enormously during the second half of the 20th century. If, in fact, before the Second World War there were about 100,000 buildings, in the 2011 building census there were three times as many. Given the limited space available, the city developed vertically. However, the growing demand for housing and infrastructure, or at least its prediction (the city's PRG of 1980 predicted that the city would have one million inhabitants in 2000), has not spared the areas at high risk of flooding, as well as the banks and, in some cases, the bed and mouth of the rivers that flow through it. Particularly significant and illustrative is the history of urbanisation near the Bisagno stream and its tributaries, such as the Rio Fereggiano. In the 1930s, the Bisagno was partly covered over to make room for road infrastructure and housing, and this trend continued until the dramatic flood of 1970, which was largely determined by the bottlenecks produced by the drainage. That episode revealed that the calculations on the maximum flow of the torrent and tributaries were completely wrong.

Genoa is also exposed for reasons related to the natural environment. A first element is the orography of the territory, which is characterised by the presence of dozens of watercourses, some of which have a significant flow rate, with slopes that in some parts of the city exceed 50%. A second factor concerns the city's position, which is barycentric with respect to an atmospheric depression, called the 'Genoa Low' by technicians, whose characteristic is the convergence of hot winds from the southern Mediterranean and cold winds from the Alps. The 'Genoa Low' is more recurrent in the autumn months and facilitates the arrival of heavy rain. Climate change is said to have made the clash between warm and cold currents more extreme than in the past. The consequence is that, while the number of rainy days is reduced, the rainfall rate, i.e. the ratio of rainfall quantity to fall time, increases. This was evident during the 1992 and 2011 floods, where the same amount of rain fell as in the 1970 flood, but in half the time (Faccini et al. 2015).

In relation to the second strand, studies have mainly focused on theoretical models on risk perception (Bracco et al. 2015) and institutional trust/confidence (Mutti, 2012), with reference to the post-flood of 2011 and 2014:

- In relation to risk perceptions, of note are those developed by Janmaimool and Watanabe (2014), according to which the perception of environmental risk is influenced both by factors related to the nature of the risk, such as the perceived probability of the event and the severity of the consequences, and by emotional and cognitive factors, such as the perceived ability to control and concern for oneself and one's loved ones; the homeostatic theory of risk by Raaijmakers et al. (2008), on the other hand, states that risk perception is influenced not only by the immediacy of danger, but also by pre-existing beliefs and attitudes. Awareness, concern and preparedness influence each other: preparedness reduces concern and, consequently, awareness. Finally, the model proposed by Wachinger et al. (2013) introduces variables such as prior experience and trust in institutions, explaining why awareness and concern are not always sufficient to foster adequate risk management. People may accept risk for perceived benefits or delegate responsibility to institutions.
- In relation to institutional trust, Bracco et al. (2015) referred to these models to analyse the communicative processes activated after the 2014 flood, and found how the media, both local and national, played a negative role in building trust relationships between the local administration and citizens, fostering accusatory social representations towards the municipality, de-responsibilising towards citizens' duties, and simplifying the complexity and difficulty of DRR. Bracco et al. (2015) also reconstruct a typology articulating four macro-attitudes in trust relations between institutions and citizens, 'mixing' two poles, 'scepticism' and 'trustworthiness'. When both are high, there is critical trust; when only the former is high, there is a rejection of the institutional message; if only the latter is high, there is uncritical trust; finally, if both are low, there is distrust, i.e. an attitude of thinking that the administration's behaviour in DRR will be negative in any case.

5.1.4. Public risk management policies: the main measures.

This section summarises the findings of research aimed at reconstructing risk policies and governance (*Disaster Risk Management*, DRM) in the urban context of Genoa. In the Annex 1, law and acts approved by multi-level governments (from local to national level) about mitigation and prevention of natural hazards, were collected and briefly described.

We introduce the topic by arguing that risk governance appears particularly complex due to the plurality of actors, the different sectoral competences and the multiplicity of operational and regulatory mechanisms that structure it and, in the specific case of Genoa, also due to its particular physical fragility, which has already been widely discussed. Understanding and analysing the underlying processes – in particular those governing the Civil Protection system – was necessary in order to identify the actions and instruments formulated and implemented that characterise and determine the policy itself.

The reconstruction was carried out using a mixed methodological approach based on a desk collection of documentary and regulatory sources and a series of semi-structured interviews conducted by the research group between 2024 and 2025 with the main actors involved in governance. The main mechanisms and actions were identified taking into account the level of governance and the phases of *the Disaster Management Cycle* (Khan, H., Vasilescu, L. G., & Khan, A., 2008; Alexander, 2002; Coppola, 2015) to which they can be traced. They were then classified according to their adherence to the specific risk (see Annex I).

Hydrogeological risk is the type that has attracted the most political attention and, for this reason, has developed a dense network of governance policies related to it over time.

The floods of 2011 and 2014 represent crucial moments for the municipality and region respectively, which have prompted the public and institutional agenda, forcing the two newly elected administrations to reconfigure their policy profiles. In particular, the Municipality of Genoa has worked hard on the governance structure in terms of preparedness and response to emergencies caused by hydrogeological weather events and to equip the authority with various structural and non-structural mitigation tools. The need to complete major hydraulic works, such as the Bisagno and Fereggiano floodways, to mention the best known, and all the other interventions on the dozens of streams and waterways that irrigate the urban fabric, was accompanied by the need to strengthen the Civil Protection system. This is why a new, highly structured Civil Protection Plan has been drawn up, which takes into account the various risks, for each of which a specific detailed operational plan is adopted. A permanent Civil Protection unit has been introduced, as well as an instrumental monitoring system - with complete weather stations, river gauges and hydrometers - and a physical monitoring system - thanks to the availability of geologists working in the municipal offices and teams of volunteers and local police patrols. The Municipal Operations Centre (COC) has also been reorganised into support functions, backed by an emergency management information system that organises and manages communications with bodies inside and outside the municipality to coordinate the various phases. In addition, a dense network of duly trained voluntary associations is directly involved in governance and is active in the preparation phases of the event, positively characterising local political action in emergency management. In fact, they play an important role by going door to door to the residents most exposed to possible flooding, informing them of the danger, evacuating vulnerable individuals and sheltering them in facilities, even in the event of landslides and mudslides, but also and above all by restoring and cleaning up the affected areas with their own equipment (water pumps, excavators, etc.).

Mayoral decrees, most of which were issued between 2015 and 2017, also represent complementary measures that integrate these risk management processes. These include: the closure of schools and universities in the event of a red weather and flood alert; the closure of premises on the lower floors of buildings located in flood zones; the obligation for condominium administrators or owners of buildings at risk to inform condominium residents about alert procedures and self-protection measures. Others specifically concern the prohibition of motorcycles and tarpaulin-covered vehicles on viaducts in the event of a strong wind warning, or the prohibition of access to the shoreline or sea access points in the event of a severe storm warning. The latter are an integral part of the risk mitigation policy, which is why the municipal Civil Protection Department has developed over the years a series of information and communication programmes aimed at citizens, with specific content for schools, such as *Pillole di Protezione Civile (Civil Protection Pills)*[4] or the national campaign in which Genoa also actively participates, *Io non rischio (I don't take risks)*[5] .

The interviews reveal that these efforts, although commendable, leave several gaps and reveal some critical issues: although the Plan is designed as an evolving tool for planning and implementing response activities in emergency situations and is therefore subject to periodic reviews, the last update to the General Report dates back to 2019, when, as a result of Article 12(4) of Legislative Decree No. 1/2018, the Plan changed its name

[4] https://www.comune.genova.it/servizi/ambiente/cultura-di-protezione-civile-pillole

[5] https://iononrischio.protezionecivile.it/it/

from Municipal Emergency Plan to Municipal Civil Protection Plan. The individual operational plans for each type of risk are years behind: Interface fires, 2017; Snow conditions, 2016; Weather and hydrogeological conditions, 2015; Seismic emergencies, 2011; Heat waves and health effects, 2005; Strong winds and storm surges, 2003. Furthermore, the participatory process for drafting this plan is still in the design phase, with the possible involvement of Unige and Fondazione Cima, and provides for the participation of stakeholders and municipal offices, while citizens are not involved due to lack of funds. With regard to the implementation of rescue operations, it has emerged that there is no control room capable of coordinating the dozens of associations that often overlap in their interventions, resulting in a lack of effectiveness. Finally, critical positions are expressed with regard to self-protection rules and recommendations in the event of intense heat.

At the regional level, however, the turning point in weather and flood risk management can be traced back to the 2014 floods. Following that event, the operational body that is now always active on this specific risk was reorganised and, thanks to agreements with the Fire Brigade Command[6], governance is more effective because constant monitoring is guaranteed for the management of reports in the event of an emergency. The new alert system has been regulated, which, in fact, anticipated the national system[7] by introducing not only the *colour* system but also the orange alert for storms, which was not planned until 2015 and which, based on the experience in Genoa, has marked its importance. The planning tools, the Libro Blu (in 2017 and the latest in 2020), have been updated with the new guidelines for municipal civil protection planning.

For other types of risk, it should be noted that, as regards forest fire prevention, since 2000 the Liguria Region has been using the National Fire Brigade for civil protection activities, fire prediction and active firefighting, and the management of forest fire volunteers. The Region provides support through alert systems – the SPIRL Liguria Region Fire Forecast Bulletin, developed by the Cima Foundation – and mitigation measures such as the Regional Fire Prevention Plan[8]. Also at the regional level, for the management of heatwave risk, an ordinance was issued just this past summer to protect outdoor workers[9] , which adopts the 2024 memorandum of understanding between the Prefecture of Genoa and other entities, including the Port Authority, Port Authority, Local Health Authority and Fire Brigade, which aims to protect workers' health by avoiding shifts during the hottest hours, providing more breaks, ensuring refrigerated premises, supplying free drinking water and air-conditioning operational vehicles. These practices had already been discussed and regulated the work of Genoa's dockworkers in 2023. The elderly, children and other vulnerable individuals are particularly exposed to the risk of heat waves, but to date there are no active policies in place to protect this category. While there is a system in place for workers that determines and warns of periods of intense heat – see ARPAL and ALISA[10] – and on the basis of this it is possible to regulate exposure to risk, this is not equally possible for vulnerable individuals. We would like to highlight a valuable initiative that addressed this gap in Genoa between 2004 and 2007, called *'i custodi sociali' (social guardians)*, promoted by the regional body ALISA, in the person of Dr Palummeri. It consists of a group of suitably trained volunteers responsible for door-to-

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[6] DGR 456/2017

[7] DGR No. 498 of 27/03/2015, 'Adoption of the colour-coded alert system update scheme' anticipates the Operational Guidelines of the Civil Protection Department of 10 February 2016, which provide guidelines for the standardisation of alert messages and related operational phases for weather and water risks, while maintaining federated alerting competence.

[8] Last updated with DGR no. 274 of 22 March 2024

[9] Ordinance no.1 of 2025

[10] Protection from heatwave risk does not fall within ARPAL's specific remit, but the functional centre nevertheless issues its own messages, incorporating those of the Ministry of Health. ALISA, on the other hand, issues its own bulletins for outdoor workers, referring to the website https://www.worklimate.it/.

door monitoring of patients in particular need of support. This practice is now diluted in regional coordination cooperatives and is activated at the request of attending physicians.

Turning now to the hydrogeological risk mitigation strategies implemented by the local government, we can say that historically they have mainly focused on hydraulic engineering projects (riverbed redevelopment, elimination of critical issues caused by narrowing and culverting) and on major infrastructure works on large torrents, thanks also to highly professional technical offices. However, over time, it has also become clear that it is necessary to monitor, survey and intervene in a timely manner throughout the area and especially in the hinterland. This is the mission of the Directorate of Hydrogeology, Geotechnics and Valley Observatory, a specific operational structure of the Municipality of Genoa that works to design and implement works and projects to combat hydrogeological instability. The provision of this type of structure is part of good DRM policy and is a response to the abolition of important bodies involved in the protection and management of the inland territory, such as the Mountain Communities, the Forestry Corps and the land reclamation consortia.

In order to be exhaustive in the description of DRM policies, it is also necessary to take into account those land-use planning mechanisms, planning documents and development strategies that promote – at least on paper – a multi-risk and multidisciplinary approach to risk management. The documents collected and analysed are numerous and fall into several levels of governance, each of which has contributed, or continues to contribute, to defining DRM policy. These include: the Municipal Urban Plan (PUC), the Sustainable Energy and Climate Action Plan (SECAP), the Green Plan, the Forest Management Plan, the Metropolitan Strategic Plan, the Covenant of Mayors, the Regional Strategy for Adaptation to Climate Change (SRACC), the Land Bank, the Regional Territorial Plan, the PR FESR 21-27, the Rural Development Plan (PSR), the Marine and Coastal Environment Protection Plan, and the Regional Prevention Plan (health). Many of these instruments promote similar objectives in the governance of a fragile territory such as Liguria. They identify strategic lines including objectives and targets for climate change adaptation and mitigation, which often coincide with the need to promote the development of inland areas to combat abandonment and neglect - causes of increased hydrogeological and fire risk - and to regenerate urban areas through *nature-based* approaches. The table 5shows some of the projects currently underway or already completed for the city of Genoa included in the SECAP[11] .

Area	Action title	Description
Civil protection	ADAPT NOW project	Development of hazard maps for phenomena linked to climate change scenarios, which will form the basis for updating the Municipal Civil Protection Plan.
Urban Planning	The Polcevera Park and the Cerchio Rosso	This is a redevelopment project of the area affected by the collapse of the Morandi bridge. It integrates sustainable mobility with landscape redevelopment through interventions that focus to mitigate hydrogeological risks and heat islands.

[11]https://smart.comune.genova.it/sites/default/files/archivio/documenti/DD-1132-2024_approv%20monitoraggio%20secap.pdf

	Corner for adaptation and climate change mitigation	Implementation of the Municipality of Genoa's Geoportal with databases that facilitate the joint interpretation of territorial data and climate-change information.
Environment and biodiversity	UnaLAB Project – Gavoglio Park	In the Lagaccio neighbourhood, a new 'urban nature' system to combat the effects of climate change, with draining paving, rain gardens, etc. It stands out for having initiating participatory design involving groups of citizens and for being a project in line with risk mitigation in the city.
Health	CLIMACTION Project	A project funded by the Ministry of Health, aimed at intervening in an area—Piazza Metastasio in Cornigliano—identified as a heat-island hotspot, in order to mitigate its effects on health.

Table 5: Some of the main projects extracted from 'First monitoring of the Sustainable Energy and Climate Action Plan (SECAP)'

5.2 Multi-risk scenarios in the Friuli UTE

5.2.1 The geophysical models: earthquake-induced tsunami and rockfalls scenarios

Physical modelling of different geo-hazards, including climate change effects, provides the basis for defining plausible (yet unobserved) multi-hazard and risk scenarios. The developed scenarios supply a systematic method for exploring how the complex interplay between hazards and urban systems may impact a society, and can be applied to support and rationalise decision making and inform preparedness for multi-risks management and mitigation. Plausible multi-hazard and multi-risk scenarios, for instance, can support the definition of detailed contexts for developing storylines that account for multiple events, namely events occurring simultaneously or in a sequence, as discussed in the following sections. Here we focus in particular on earthquakes and cascading hazards, such as tsunamis or landslides induced by seismic events.

a. *Earthquake-induced tsunami hazard scenarios*

The northeastern coast of the Adriatic Sea is exposed to various natural hazards, including floods, severe storms, wildfires, earthquakes, tsunamis, and meteotsunamis, as well as Sea Level Rise (SLR). Among these, tsunamis, though less frequent, pose a significant risk due to their potential for catastrophic impacts on coastal communities. While strong earthquake-induced tsunamis are relatively less frequent in the Northern Adriatic Sea, the impact of moderate to strong tsunamis could be considerable due to the high exposure and vulnerability of coastal communities.

High-resolution earthquake-induced tsunami hazard assessment has been carried out for the Northern Adriatic coast, including the UTE-FVG territory, based on tsunami scenarios modeling for a wide set of potential sources, the creation of a database of precomputed scenarios, as well as their aggregation and mapping. The research aims to address a critical gap in detailed tsunami hazard mapping, especially relevant for the Northern Adriatic due to its shallow bathymetry. This study, in fact, aims to move beyond single-event scenarios and available regional models (e.g. TSUMAPS-NEAM model, https://hazard.tsunamidata.org/?dataset=NEAMTHM18), by developing aggregated hazard maps and demonstrating the importance of high-resolution data for local impact assessment.

The methodological innovation relies on the computation and aggregation of a wide set of potential tsunamigenic earthquake scenarios at multiple distances. The approach involves simulating the three phases of a tsunami: source modeling, propagation, and coastal inundation. This is achieved using the NAMI DANCE code (e.g., Veliglou et al. 2016, and references therein), a specialized code based on the solution of non-linear shallow water equations, which is a standard approximation for simulating tsunami waves propagation. The modeling incorporates topographic and bathymetric data through a nested-grid system to ensure both computational efficiency and local accuracy.

Specifically, the performed tsunami hazard analysis builds upon potential tsunamigenic earthquake sources from existing databases (e.g., DISS-3.3.0 database), grouped according to magnitude and source-to-site distance ranges adopted in CAT-INGV's tsunami decision matrix, to ensure comprehensive scenario coverage. The modeling relies on a multi-scale modeling approach with a newly developed high-resolution 25 m topo-bathymetric grid, down-sampled and revised from higher-resolution data from Trobec et al. (2018). This comprehensive grid integrates multiple datasets (e.g. GEBCO for the wider Mediterranean, and EMODnet for the North Adriatic), and was specifically developed to address known limitations in representing critical coastal environments, particularly the sensitive lagoon areas between Lignano and Grado. Accordingly, the modeling system consists of three nested topographic-bathymeteric grids (460 m → 115 m → 25 m) , allowing for accurate far-field wave propagation from potential earthquakes of Mmax ≥ 6.5 and rather precise simulation of local inundation patterns at 25 m resolution. The results demonstrate significant improvements in modeling wave penetration into lagoon systems and river mouths. However, the topo-bathymetry data at 20 m resolution might still not be able to capture perfectly all fine coastal features, suggesting that higher-resolution data would be beneficial for developing more and more detailed inundation maps.

The primary outcomes consist of a set of tsunami hazard assessment measures and maps. The results from aggregated scenarios, including key outputs such as maximum wave amplitude maps, are provided at the shoreline and at specific Points of Interest (POIs) of the UTE-FVG (Figure 31). For emergency response, Estimated Time of Arrival (ETA) tables for key locations like Trieste, Monfalcone, Grado, and Lignano have been produced, providing critical lead-time information. Furthermore, a comprehensive physics-based dataset of tsunami scenarios, including synthetic mareograms and numerical grid files, has been generated. For the individual scenarios, essential hazard parameters were computed, including maximum wave amplitudes, estimated time of arrival, detailed inundation extent and flow depth maps. Stakeholders requirements were taken into account, at each stage of the analysis, and turned out valuable especially in defining the outputs.

According to the resulting tsunami inundation maps, the northwestern sector of the UTE-FVG, with its low elevation, is highly susceptible to inundation; incorporating projections for sea-level rise would substantially increase the modeled inundation area and severity. As coastal regions face increasing pressures, these updated maps represent a forward step in tsunami hazard and risk assessment capabilities, highlighting the need to timely integrate this often-neglected risk into disaster preparedness within the UTE-FVG. The results can be combined with high resolution exposure and vulnerability data to produce reliable tsunami risk maps for the study regions, including the coastal area of Friuli Venezia Giulia Region, where the methodology has been developed. The aim is to assess the feasibility of using a multi-scenario, multi-resolution modelling approach to contribute to the definition of actionable site targeted tsunami hazard estimates for improved emergency and urban planning in the Friuli-Venezia Giulia (FVG) coastal region.

The proposed methodology for tsunami hazard assessment and its application to the UTE-FVG, are described in the article *“Scenario-based tsunami hazard assessment for Northeastern Adriatic coasts”* by *Peresan and Hassan (Mediterranean Geoscience Reviews, 6(2), 87-110; 2024. Available at: https://link.springer.com/article/10.1007/s42990-024-00114-w).* The methodology is fully replicable in other Adriatic and Mediterranean coastal areas with similar tectonic settings and data availability, as demonstrated by its application to the Albanian coastal area, described in the article *“Simulation of large plausible tsunami scenarios associated with the 2019 Durres (Albania)* earthquake *source and adjacent seismogenic zones”* by Xafaj et al. (2024), available at https://link.springer.com/article/10.1007/s42990-024-00122-w.

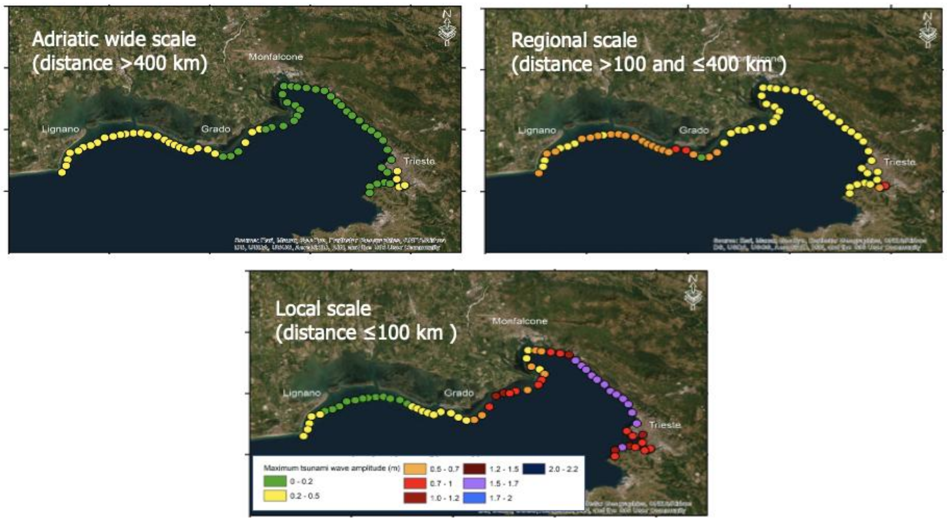

Figure 31: Maps of the maximum tsunami wave amplitude computed at the selected POIs for: a) the Adriatic-wide sources, located at distances greater than 400 km from the area of interest; b) the regional tsunamigenic sources; c) the local sources, located at distances less than 100 km from the area of interest (modified after Peresan and Hassan, 2024).

b. Earthquake-Induced Rockfall Scenarios

After an earthquake event, major ground effects include landslides, and in Italy, the most common type of earthquake-induced landslides are rockfalls. The assessment of the extent and magnitude of an earthquake-induced landslide event is of paramount importance for both preparedness and response operations. In the study *“An approach to rockfall hazard scenarios based on earthquake ground motion"* by Peresan et al. (2024), available at: https://link.springer.com/chapter/10.1007/978-3-031-72736-8_8). We explored the combined use of two physics-based methods (i.e. NDSHA) for both earthquake and rockfall modeling to contribute towards a better understanding of the triggering mechanisms and characterization of seismically induced rockfalls.

This involved physics-based ground motion simulations of the seismic sequence following the 1976 Friuli earthquake, which allowed for the generation of synthetic seismograms. Peresan et al. (2024) modeled earthquake scenarios considering both point and extended source model approximations, using algorithms that account for the rupture process and the effects of directivity. From the complete set of synthetic seismograms, various maps of ground shaking parameters, such as Peak Ground Acceleration (PGA) at bedrock, were extracted. These ground shaking scenarios, which account for increasingly complex details including multiple seismic events, were then used to drive a three-dimensional model for rockfalls, which describes the rockfalls trajectories.

The application of this modeling chain to the Friuli 1976 event suggests an advantage of using multiple seismic sources over a single source (Figure 32) and highlights the importance of including topographic effects in the ground shaking simulations. The results show that this approach may effectively capture the main spatial patterns of observed rockfalls, evidencing the opportunity to further investigate the cumulative effect of complex seismic sequences and their influence on modulating landslide susceptibility. This refined modeling chain can be calibrated and potentially applied in real time after an earthquake event, providing critical information to guide emergency response and mitigation efforts. The resulting scenarios can also be used to develop storylines, which might be especially interesting when dealing with transportation infrastructures (e.g. roads, railways, bridges), for which the potential rockfall trajectories are relevant.

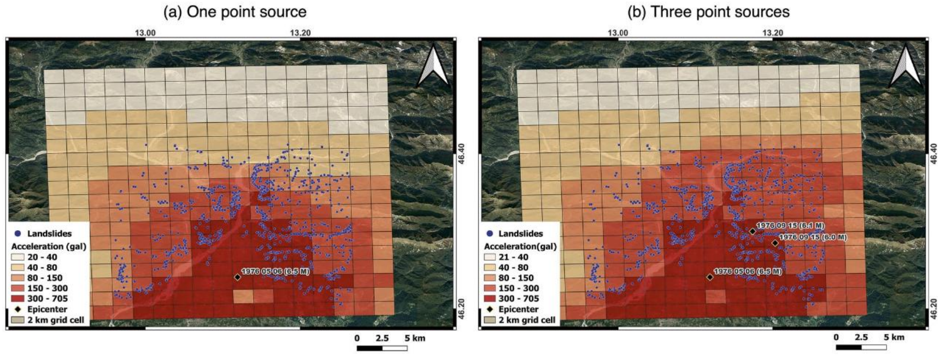

Figure 32: Spatial distribution of modeled ground shaking (PGA [gal]) for: (a) the main shock point source, (b) the three aggregated point sources. The locations of rockfalls are marked by blue dots. The grid cells are colored according to the PGA values computed at their central points. The black diamonds indicate the epicenters of the earthquakes (modified after Peresan et al., 2024).

5.2.2 Multi-hazard exposure assessment

Characterizing exposed assets such as populations, buildings, and infrastructure is a required step in order to identify potential damages and losses and, consequently, to develop more effective and targeted risk mitigation strategies. However, exposure assessment is itself a complex task, as exposed assets are dynamic, interrelated, and contribute differently to the overall damages and losses depending on the hazardous phenomena affecting them. Currently there are few examples of high-resolution exposure layers that comprehensively account for features relevant to multiple hazards. Additionally, the monetary value of exposed assets is rarely available in these datasets, despite its fundamental relevance for associating and comparing financial exposure across different hazardous phenomena. Importantly, some exposure-related information contained within building footprints remains somewhat overlooked and could significantly enhance current exposure layers; this includes detailed geometric data related to building area, perimeter, and shape factors, which can serve as proxies for structural irregularity and vulnerability. While some studies have demonstrated the effectiveness of openly available datasets like OpenStreetMap (OSM) and satellite imagery in constructing exposure models for seismic and multi-hazard risk assessment, the full potential of integrating high-resolution geometric indicators is yet to be widely realized.

A methodology is therefore proposed for developing an exposure model for population and residential buildings at multiple spatial scales, enabling more precise and context-specific multi-hazard risk analyses in vulnerable coastal regions. The methodology is preliminarily developed and applied to the UTE-FVG coastal area, located in the northern Adriatic, which is prone to multiple hazards, such as seismically-induced tsunamis, meteorological events, coastal erosion and subsidence. The population exposure layer is developed integrating population data with demographic characteristics and socio-economic indicators. Specifically, population exposure is developed by integrating the Meta dataset and the available census data. Meta data is available globally at 30-meter grid points, while census data is aggregated at the census unit level. Census population data was used to refine the Meta data, combining the reliability of the census data with the higher resolution of the Meta data. In parallel, the residential building exposure layer is assembled combining two data sources: the last updated building census data and digital building footprints. The method develops in three steps: identification of height classes, extraction of building characteristics from footprints, and integration with census data. It provides information about: geographic distribution, age of construction or retrofit, number of storeys, construction material types, average built-up area, structural replacement cost, and structural regularity. The GED4All taxonomy was used for standardized exposure dataset development. These data layers are made available at two resolutions: 30m and 100m (Figure 33), with information also provided at the census unit level.

The methodology may provide information potentially useful to support local urban scale planning, prioritization of data collection, and resilient land use planning, with outputs including population and building maps aligned with a standard multi-hazard taxonomy, facilitating granular impact assessment and building stock interventions. The approach is designed to be transferable and applicable to other coastal areas worldwide, as it relies on publicly available datasets such as OpenStreetMap building footprints and Meta population dataset; it also requires inputs in the form of ancillary data (e.g. Census data), which are increasingly made available by governments and research institutions.

The proposed methodology and its application to a selected urban area within the UTE-FVG, namely the city of Lignano Sabbiadoro, are described in the article *"High-resolution multi-hazard residential buildings and population exposure model for coastal areas: a case study in northeastern Italy" (Badreldin, Scaini, Hassan and Peresan, 2025. Available at: https://www.sciencedirect.com/science/article/pii/S2212420925002274).*

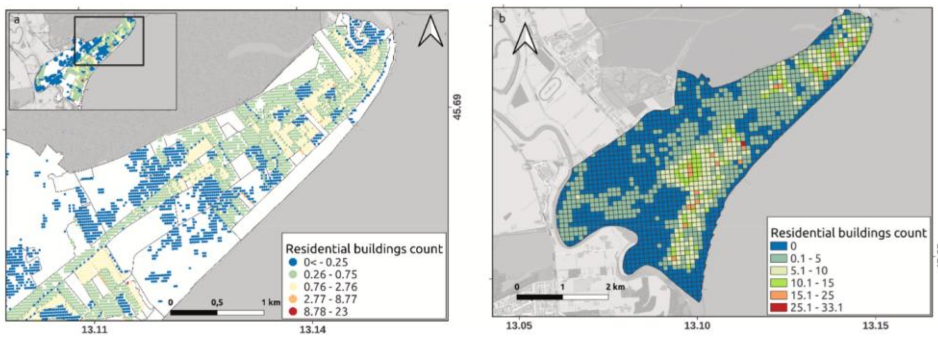

Figure 33: Exposure layers produced for residential buildings: a) disaggregated on a regular 30 m grid and (b) aggregated on a 100 m regular grid (after Badreldin et al., 2025).

5.2.3 Risk scenarios: earthquake-induced tsunami

While tsunamis in Northern Adriatic are infrequent, their potential for severe impacts on densely populated or economically critical coastal areas, such as the tourist hub of Lignano Sabbiadoro, calls for a detailed risk assessment. Accurate coastal risk assessment requires high-resolution data for each of its components (hazard, exposure, and vulnerability), ensuring spatial coherence between inundation models and population/building exposure models. Exposure models quantify and characterise the assets at risk, e.g. describing building typologies and population distribution, while vulnerability models estimate their susceptibility to tsunami forces, e.g. based on fragility curves and damage indices.

The research carried out within the UTE-FVG aims at integrating the high-resolution tsunami hazard modelling, performed using multi-scale a nested topo-bathymetric grid (at 25 m resolution), with the refined exposure datasets at 30 m resolution (Badreldin et al., 2025), described in previous sections. The Lignano case study involved classification of 36 building typologies into eight tsunami-relevant features, based on material, age, height, and reflecting both pre- and post-seismic building code. Exposure layers aim to capture the distribution of buildings and residents, including the vertical and horizontal buildings regularity or the spatial population distribution. Vulnerability is quantified using a Damage Index (DI), linking structural attributes to expected damage levels, while consequence models translate inundation and damage into population impact and financial losses. Preliminary results indicate that Lignano's building stock, predominantly consisting of low- and mid-rise unreinforced masonry, is largely resilient to moderate tsunami scenarios, with most structures expected to experience no or slight non-structural damage. A minority of mid-rise masonry buildings may experience moderate damage, highlighting priority targets for mitigation. Reinforced concrete and modern seismic-code buildings exhibit negligible structural vulnerability. Economic losses from the modelled scenario are predominantly associated with minor and moderate damage categories.

5.2.4 Historical review of key events in UTE FVG

The historical analysis of hydrogeological risk and extreme climatic events in the coastal cities of Friuli-Venezia Giulia in recent years reveals a picture of growing complexity and vulnerability. The territories of Trieste, Monfalcone, Grado, and Lignano, although distinct in their specific geomorphological configurations, share a common trajectory: the progressive intensification of extreme meteorological phenomena, whose impact is significantly amplified by historical and intensive human activities.

Trieste

The city of Trieste and its province present a particularly complex geographical and geomorphological context, making them intrinsically vulnerable to a variety of hydrogeological phenomena. The area's conformation, a delicate balance between the Karst area and the Adriatic coastline, creates an environment where the interaction between geological, climatic, and anthropic factors can trigger hazard events.

The period between the mid-1970s and the end of the 1980s marks the beginning of greater awareness of hydrogeological risk at the regional and national levels. In this context, the first legislative responses began to outline a more structured approach. Regional Law no. 68 of 28 August 1982 and the subsequent Regional Law no. 27 of 9 May 1988 represent the first attempts at an organic intervention for "calamitous events and exceptional weather events" (https://lexview-int.regione.fvg.it/FontiNormative/xml/IndiceLex.aspx?anno=2002&legge=16&fx=lex).

A significant climatic event that directly struck the province of Trieste during this period was the disastrous storm of 29 July 1983. This phenomenon, described as "the most spectacular and disastrous storm," required the intervention of the Fire Brigade for over fifty operations in just a few hours. In Muggia, a large poplar tree uprooted by the wind fell onto a parked car, causing extensive damage but, fortunately, no injuries (https://www.informatrieste.eu/ts/blog/29-luglio-1983-a-trieste-arrivo-la-tempesta-piu-spettacolare-e-disastrosa).

The 1990s marked a phase of increased frequency and intensity of severe weather events in Italy. Friuli was hit by torrential rains, which caused flooding, widespread damage, and the interruption of the railway line connecting Udine to Trieste. The event, along with those of 1998 and 2004, was later included among the reference events for regional hydraulic intervention planning with 200-year return times (https://www.regione.fvg.it/rafvg/export/sites/default/RAFVG/ambiente-territorio/geologia/FOGLIA24/allegati/PAIR_Allegato_01_relazione_illustrativa.pdf).

Within this decade, several significant events were recorded: a thunderstorm with hail on the night of 2 June 1993, and a violent downpour that hit Grado and Fiumicello on the night of 11 June 1995. A notable and contrasting aspect emerges from the analysis of the severe downpour that affected the Isontino area and the lower Friulian plain on 19 September 1995. While stations like Cervignano del Friuli recorded 168.3 mm of rain in a few hours and Udine 135.6 mm, with extensive damage estimated in the billions of lire to vineyards, the coastal areas were almost completely spared. In Trieste, in particular, only 14.8 mm of rain fell, and in Fossalon di Grado 9.0 mm (http://www.meteogo.it/archivio_accadde_questa_settimana.html). This disparity highlights the role of micro-geography and the specificity of convective phenomena, which can discharge their intensity in circumscribed areas, offering relative protection to other zones, such as the Trieste coast on this specific occasion.

The flood of October 1998 is another historical reference point for the Friuli Venezia Giulia Region. Although the sources do not provide precise details on its impact in Trieste, its inclusion in regional prevention plans confirms its relevance as one of the most significant events of the decade.

An exceptional phenomenon, differing from traditional hazard events linked to excess water, occurred in January 1999. On 24 and 25 January, the surface of the Gulf of Trieste froze over extensively. An event of this magnitude, affecting almost the entire coastal strip, had never occurred since. The most unique aspect is that the event happened in an anomalous climatic context for the phenomenon: not during a cold snap or with a strong Bora wind, but in the presence of a mild anticyclone, with temperatures on the Karst Plateau reaching 13°C. This episode demonstrates how hydrogeological instability can also manifest through unconventional but equally exceptional phenomena, highlighting the complex interactions between the atmosphere, hydrosphere, and cryosphere in a vulnerable ecosystem like the Gulf of Trieste (https://www.aametsoc.org/post/mare-gelato-trieste-gennaio-1999).

The first decade of the new millennium is characterized by events that highlight a growing vulnerability of the urban fabric and the territory. A particularly significant summer was that of 2003, remembered for record temperatures and unprecedented drought. Data indicate that just 81 mm of rain fell on Trieste during the entire season, less than one-fifth of the statistical average. This drought phenomenon, seemingly the opposite of hydrogeological instability, is actually a crucial risk factor. Arid and compacted soils, lacking the vegetation that consolidates them, lose their ability to absorb water. Consequently, when intense rain events occur, surface runoff is massive and rapid, exponentially increasing the risk of flash floods and landslides.

Other severe weather events affected Friuli Venezia Giulia during this period, including a strong thunderstorm on 1 July 2005 in the Isontino area, which caused flooding and power line interruptions. The 2009 flood is also cited as a reference event for regional planning, indicating its severity at the river basin level. Although direct details on Trieste are not provided, the intensity of the rain and the impact on urban drainage systems became evident in the following years.

The following decade is marked by the recurrence and intensification of extreme weather events, which are beginning to be perceived as a "new normal" due to climate change. The All Saints' Day flood of 2010, although it hit the provinces of Pordenone and the entire Veneto region more devastatingly, is considered a watershed event for regional hydrogeological risk management (https://www.regione.fvg.it/rafvg/comunicati/comunicato.act;jsessionid=269BDE76F49FAAD2B81CC55ECB3CF029?dir=/rafvg/cms/RAFVG/notiziedallagiunta/&nm=20110720123718007). A downpour hit Trieste on 22 September 2010, with a rain intensity not seen in the city for 88 years, causing extensive flooding and disruption.

A detailed analysis of this period reveals the presence of a particularly vulnerable area: the Strada Costiera (Coastal Road). On 12 October 2012, a "significant" landslide broke away from the mountain, beyond the natural tunnel, invading both carriageways and blocking traffic between Trieste and Sistiana. Vehicles leaving the city were diverted to alternative routes. Less than two years later, on the night between 21 and 22 April 2014, another landslide caused by 24 hours of intense rain occurred on the same artery, near the Hotel Riviera. Large pine trees, roots, and soil fell onto the road, forcing its closure for several days. The recurrence of these events on a vital communication infrastructure for the province is not coincidental but indicates the existence of an area of high geological fragility. The Strada Costiera acts as a risk "hotspot," where the slope's geology and high precipitation combine to create a persistent vulnerability that requires continuous maintenance and monitoring (https://www.ilpiccolo.it/cronaca/frana-in-costiera-strada-bloccata-in-entrambi-i-sensi-dbctljxz).

Another large-scale event was the violent downpour of 12 June 2016. In less than two hours, 24 millimeters of water fell, turning streets into torrents and causing dozens of manholes to "pop." The water reached 50 centimeters on the Rive, flooding dozens of businesses. The main thoroughfare adjacent to the Ferriera (ironworks) and the basements of the Ospedale Maggiore (Main Hospital) were also flooded, although the clinical wards were not compromised (https://www.ilpiccolo.it/cronaca/due-ore-di-nubifragio-allagano-trieste-foto-e-video-bh1guova).

The most recent years have seen a further acceleration of extreme phenomena, often with direct and immediate consequences on the urban fabric. At the same time, there is greater institutional attention and a more proactive approach to prevention.

A hallmark of this period is the intensification of exceptional storm surges. On 27 October 2023, a strong storm surge, accompanied by a high tide that reached 169 cm, submerged Piazza dell'Unità d'Italia, the Molo Audace, and the Rive, causing disruption and traffic chaos. A few days later, on 3 November, an even more violent storm surge, fueled by a rare Libeccio (south-westerly) wind, devastated the Barcola waterfront (https://www.quotidiano.net/cronaca/muggia-grado-alta-marea-maltempo-utgt2sh2). The event caused millions of euros in damage, destroying beach resorts, kiosks, and the small marina. The force of the waves uprooted the iconic "Mula de Barcola" statue and damaged the protective barriers. Initial damage estimates reported a sum of 2 million euros, but later a total figure of 15 million euros for reconstruction was mentioned. The Region responded by allocating 150 million euros for the damages (https://telequattro.medianordest.it/34969/trieste-maltempo-fedriga-150-milioni-in-piu-per-i-danni-ai-privati-piu-fondi-alle-imprese/?noamp=mobile). This phenomenon is closely linked to climate change, as indicated by the sea temperature being almost 2°C above the seasonal norm.

Finally, a "water bomb" event that occurred in early September 2025 is highlighted. The downpour dumped 40 millimeters of rain in less than 30 minutes, overwhelming the urban drainage system. Water invaded the Rive and Viale Miramare with a height of over 30 cm, causing blackouts, flooding basements and shops (https://www.ilfriuliveneziagiulia.it/nubifragio-su-trieste-strade-allagate-alberi-caduti-e-oltre-100-richieste-di-soccorso/). Despite the violence of the phenomenon, the damage was described by institutional sources as "limited thanks to regional prevention." This statement marks a shift in the narrative of instability: damage is no longer seen as inevitable, but as an outcome that can be mitigated by proactive planning and maintenance.

MONFALCONE

The city of Monfalcone is situated on a narrow transition strip between the limestone hills of the Karst plateau to the north and the alluvial coastal plain of the Isonzo River to the south. This geomorphological duality, combined with industrial and demographic development that began in the early decades of the 20th century,

has generated a complex territorial framework in which natural vulnerabilities, reshaped by anthropic action, have emerged.
Reconstructing a detailed chronology of the hydrogeological hazard events that have specifically affected Monfalcone is complex. Available historical sources tend to focus on regional-scale events, without always detailing the local impacts. However, it is possible to identify some recurring periods and types of events.
On several occasions during the 20th century, the floods of the Isonzo River caused concern for the areas closest to the river. Although there are no reports of catastrophic direct flooding of the urban center comparable to other regional contexts, significant flood events have certainly put stress on the embankment system and floodplain areas. Local historical memory and journalistic chronicles, although not systematically collected in digital databases, report flooding in the countryside and in the lowest-lying areas coinciding with major river floods.
More frequent and documented, albeit in a too-general form, are floods in urban areas following intense downpours. Underpasses, recently urbanized areas, and former marshy zones have proven particularly vulnerable. These events are the direct consequence of the interaction between exceptional rainfall and an urban drainage system that has been modified and is partly undersized for the current land configuration.
An example of an extreme weather event that hit the area is the "great snowfall of 1985" (https://www.ilpiccolo.it/cronaca/la-grande-nevicata-del-1985-a-gorizia-e-monfalcone-e-la-spiaggia-di-grado-ghiacciata-mn50zma6), which, while not a hydrogeological instability event in the strict sense, highlighted the territory's vulnerability to exceptional climatic events.
The chronicle of significant landslide events directly affecting the town of Monfalcone is scarce. However, the potential risk is well-known and monitored. Civil protection plans and territorial planning take into account the possibility of collapses or slides, especially during prolonged rainy events or seismic events. Consultation of official databases and news archives has not revealed any significant-magnitude landslide events that have affected the town center or primary infrastructures of the Municipality of Monfalcone within the considered timeframe. The landslide risk is therefore classified as low and confined to possible localized collapses from the Karst slope, not representing the main hydrogeological criticality of the territory (https://www.progettoiffi.isprambiente.it/).
In October 1987, an exceptional meteorological event struck the Isontino area. Chronicles report a "water avalanche" over Gorizia, with record rainfall (over 300 mm in less than 24 hours and peaks of 189 mm in 6 hours). Although the focus was on Gorizia, this event caused a significant flood of the Isonzo and hydraulic stress on the entire plain, including Monfalcone, highlighting the risk arising from stationary precipitation.
In September 1998, a major flood hit several areas of Friuli. In the Isontino area, significant floods and widespread flooding were recorded due to soil saturation and the intensity of the rains, which overwhelmed the land reclamation (drainage) systems.
It is in the period between 2006 and 2015 that Monfalcone's hydraulic vulnerability becomes evident and recurrent, thanks also to the greater availability of data. The events are no longer "exceptional" but become a constant news item with every intense downpour (https://www.meteo.fvg.it/pubblicazioni.php).
In December 2009, a historic flood of the Isonzo River was recorded. In Gradisca, the hydrometer reached a record level (cited as 9.47 meters), which would become the benchmark for subsequent risk assessments. Although the embankments downstream (and thus protecting Monfalcone) held, the event demonstrated the persistent and serious danger of the river.
In July 2011, a series of violent summer thunderstorms caused widespread and repeated flooding. The historically most critical areas emerged: Via Valentinis, Via Bagni, Viale San Marco. The streets transformed into canals, with dozens of basements and garages flooded. The cause was the inability of the sewage network and drains (often clogged) to handle such intense volumes of water in a short time (https://www.ilpiccolo.it/cronaca/mezzora-di-pioggia-manda-di-nuovo-sottacqua-la-citta-mbn1a22s).
In July 2014, a violent and sudden summer downpour hit the city. In a short time, large quantities of rain fell, overwhelming the sewage system. Streets (e.g., Via Romana area, Via Valentinis), underpasses, and basements

flooded. The event highlighted the insufficiency of the urban drainage system in the face of extreme precipitation peaks and the rapid response of the Canale de' Dottori, which struggled to drain the water coming from the Karst Plateau.
The last few years are characterized by a growing frequency of extreme events that lead to the issuance of the highest Civil Protection alerts (Red Alert), demonstrating full awareness of the multifactorial risk.
In November 2019, an intense Atlantic perturbation brought exceptional rains across the entire region. In Monfalcone, an alert was triggered for hydrogeological risk. The combination of intense rains on the Karst (swelling the canals), Isonzo floods, and a high sea level (Sirocco wind) put the city's entire hydraulic system under maximum pressure.
In June 2020, another strong wave of bad weather caused widespread flooding in various areas of the city, affecting both roads and some private homes.
In October 2021, a significant event combined intense rain, sirocco wind, and high tide. This combination is the worst for Monfalcone: the tide blocks the normal outflow of drainage canals to the sea, "plugging" the system and worsening urban flooding. The affected areas were the same (Via Valentinis, Via Delle Vigne, Via Colombo), in addition to critical issues on the SS14 road and at Marina Julia (https://goriziaoggi.news/2021/10/07/maltempo-allagamenti-in-varie-zone-della-citta-a-monfalcone/).
In July 2022, a vast and disastrous fire raged on the Karst between Monfalcone, Doberdò, and Merna. Although not a flooding event, it is a critical hydrogeological phenomenon: the destruction of vegetation (about 4000 hectares) drastically alters the permeability of the Karst soil, increasing the risk of surface runoff and debris flows during subsequent rains.
In September 2022, new intense floods in the city following strong thunderstorms. Attention focused on the state of the sewage network (gullies and manholes) and stormwater management, confirming that risk of urban pluvial flooding is now a primary and recurrent criticality.
In October 2023, an event stood out from the previous ones. Following torrential rains on the upper Isonzo basin (in Slovenia), the planned opening of upstream dams released an enormous quantity of timber (uprooted trees) into the river. This mass of logs reached the sea and washed up along the entire Monfalcone coastline, particularly at Marina Nova. While not an urban flood, it was a hydraulic event with serious environmental and economic consequences for the coast (https://www.il-meridiano.it/notizie/7620-maltempo-il-punto-su-monfalcone.html).
In September 2024, more strong thunderstorms, with accumulations of 60-70 mm in a few hours on the pre-alpine foothills and the Karst, caused significant flooding in Monfalcone and Staranzano. This event is a textbook example of the rapid response of the Karst basin, whose waters flow quickly downstream, overloading the canal system and the urban network.
The evolution of these critical issues has demanded a radical rethinking of risk management strategies, moving from a reactive and sectoral approach to integrated and proactive management. The strategy based almost exclusively on strengthening the Isonzo embankments has been supplemented by interventions aimed at mitigating urban and Karst risk. These include upgrading the sewage network (with attempts to separate storm and wastewater to reduce the load on treatment plants), cleaning and strengthening the reclamation and spring-water canals, and designing urban expansion (retention) basins. The latter are essential for holding water volumes during rain peaks, releasing them in a controlled manner when the network is able to handle them.
The awareness that coastal risk and the intensification of precipitation are long-term trends is pushing towards adaptation logics. This includes planning for the resilience of critical infrastructures (port and industrial areas) and promoting nature-based solutions, such as restoring small wetlands or increasing permeable surfaces in the city to reduce surface water runoff.

Grado

The city of Grado has always existed in a delicate balance with water. Its history is intrinsically linked to the lagoon that surrounds it, an environment as fascinating as it is fragile. A chronological and contextual analysis

of Grado's hydrogeological instability reveals a growing vulnerability, the result of a complex interaction between natural factors and intense anthropic activity.
Low-lying coastal zones are among the environments most vulnerable to the effects of climate change. The rise in mean sea level, combined with the increased frequency and intensity of extreme weather events, poses a direct threat to the safety of populations, infrastructures, and ecosystems.
The city of Grado is located on the largest island of an archipelago at the northern end of the Adriatic Sea. The lagoon of the same name is the second largest in the Mediterranean and constitutes an ecosystem of exceptional environmental value. From a geological point of view, the area is the result of the gradual progression of the Isonzo River delta and complex Holocene sedimentary dynamics. The soils are predominantly composed of sands, silts, and clays of alluvial and marine origin, characterized by low load-bearing capacity and high compressibility (Carulli, 20129). The average altitude of the historic center is only 1-2 meters above mean sea level, making the area intrinsically exposed to the "acqua alta" (high water) phenomenon.
Reconstructing a complete chronology of all hydrogeological events is complex, but it is possible to identify some of the most significant episodes that have marked the last fifty years, showing a clear trend of increasing frequency and intensity.
In January 1985, an exceptional cold wave, remembered as the "snowfall of the century," led to an event as rare as it was evocative: the beach and part of the Grado lagoon froze. Although not a flood, the event testifies to the growing extremization of the climate.
In June 1995, a violent downpour, accompanied by a strong hailstorm, hit the Grado and Fiumicello area, causing significant disruption and damage to crops, highlighting vulnerability even to intense rainfall events.
In the first decade of the 2000s, several "acqua alta" episodes occurred, especially in the autumn months, which began to make clear the need for a rethinking of the historic center's defenses.
In November 2012, a series of intense storm surges hit the coast of Friuli-Venezia Giulia. In Grado, significant tide peaks were recorded, causing flooding in the historic center and alarming the population and authorities.
In October 2018, Storm Vaia, although it hit the mountain areas with greater violence, also made its effects felt on the coast. Strong sirocco winds generated an exceptional tidal wave which, combined with the astronomical high tide, caused extensive flooding and damage to beach infrastructure.
In November 2019, Grado, like Venice, suffered a series of very sustained "acqua alta" events that repeatedly invaded the lowest areas of the city, including the Mandracchio port and the historic center.
In November 2022, one of the most critical events of recent decades was recorded. On 5 November, due to a strong libecciata (south-westerly gale), the sea level reached an exceptional peak of 170 cm above mean sea level. Vast areas of the city, including those considered safer, were submerged, causing extensive damage to public buildings, businesses, and private homes.
The management of hydrogeological risk in Grado is entrusted to a multi-level approach. At the basin level, the Eastern Alps District Basin Authority has drawn up the Flood Risk Management Plan (PGRA) (2021), in implementation of the European Directive 2007/60/EC. The plan maps areas with P1 (low), P2 (medium), and P3 (high) hazard levels and defines safety objectives. For Grado, identified as a significant risk area, the plan includes structural measures (raising and strengthening defenses, upgrading the drainage network) and non-structural measures (improving warning systems, urban planning).
The future challenge consists in moving beyond traditional "grey" defense works (walls, dams) and integrating nature-based solutions, such as the restoration of salt marshes and lagoon wetlands, which can help dissipate wave energy and improve the overall resilience of the lagoon ecosystem.

Lignano

Lignano Sabbiadoro, situated between the mouth of the Tagliamento River and the Marano lagoon, has always been subject to a delicate hydrogeological balance, now severely tested by climate change and strong human activities. Its current identity is, for all intents and purposes, the product of a radical transformation, which occurred with extraordinary rapidity during the 20th century.

This metamorphosis began with the first, timid reclamation works in the '20s and '30s, but it was in the post-war period that Lignano's destiny changed forever. In less than fifty years, a natural environment that was intrinsically dynamic and unstable was "fixed" by cement, harnessed into urban geometries, and transformed into one of the main capitals of European seaside tourism. This anthropic conquest came at a very high cost: it abruptly interrupted natural geomorphological processes (such as dune mobility, coastline evolution, and sediment supply), effectively laying the foundations for the current, acute hydrogeological vulnerability. The territory was designed and built ignoring, or perhaps underestimating, its intrinsic amphibious nature (Zunica, 1995).

The erosion of the Lignano coastline is a long-standing process, but one that has undergone a drastic and documented acceleration (Fontolan, 2006). If in the '90s and early 2000s the phenomenon was considered chronic but manageable, often addressed with periodic replenishments defined as "maintenance," the last decade has seen a veritable escalation of extreme events. These have required interventions that are no longer planned, but purely emergency-based.

The cause of this phenomenon is to be found in a complex web of natural and anthropic factors. On one hand, sea level rise and the increased frequency and intensity of storm surges, linked to climate change, accelerate the erosive process. On the other hand, the reduction of solid transport by rivers, due to the excavation of aggregates and the construction of dams along their courses, deprives the coast of its natural nourishment.

If the sea threatens the coast, the Tagliamento River represents a potential danger for the hinterland. Although Lignano has not historically been hit by devastating direct river floods like nearby Latisana and Pertegada (recalling the disastrous floods of 1823, 1965, and 1966), its position at the river's mouth places it in a vulnerable condition.

More pressing and frequent is the problem of urban flooding. Lignano's sewage network, developed at different times and under the pressure of rapid urbanization, has proven inadequate on several occasions to handle "water bombs," increasingly common extreme weather events.

Further complicating the picture is the phenomenon of subsidence, a slow and progressive sinking of the ground. For the Lignano area, data indicate a lowering of about 4 mm per year. This process, partly natural due to the compaction of recent sediments, has been accelerated in the past by the extraction of fluids from the subsoil and by reclamation works. Subsidence, combined with sea level rise (eustatism), significantly increases the territory's vulnerability to marine ingress and flooding (Carbognin et al. 2004).

The chronological analysis of hydrogeological events that have affected the Lignano peninsula highlights a clear evolution of the risk profile. A transition is observed from chronic and slow processes, dominant in the second half of the 20th century, to a marked frequency of acute, intense, and often combined events in the 21st century.

The initial phase is marked by the increase in coastal erosion. This slow but structural process is a direct consequence of the drastic alteration of the Tagliamento River's sediment balance, whose delta generated the peninsula itself. The hydraulic regulation of the mountain basin and, above all, the massive removal of aggregates from the riverbed have almost zeroed the natural solid supply to the mouth, depriving the coastline of its nourishment and triggering a structural retreat (Fontolan et al. 2012). Superimposed on this underlying dynamic, in the 1991-2004 decade, are the river flood events (e.g., October 1998, October 2004). These episodes, originating from extensive and persistent precipitation in the mountain catchment area, while not causing direct flooding in the tourist center, are crucial: they represent the reference events used in the Hydrogeological Asset Plans (PAI) to model the hydraulic hazard of the entire delta system on which Lignano stands (https://distrettoalpiorientali.it/wp-content/uploads/2023/02/PGRA_rapporto_preliminare_assoggettabilit_.pdf).

However, it is the last decade (ca. 2014-2024) that shows an alarming acceleration and, above all, a diversification of risk. Two distinct types of high-frequency crises emerge that directly affect the urban fabric. Urban Floods are generated no longer by river floods, but by stationary or self-regenerating thunderstorm cells, a phenomenon consistent with global projections on the intensification of extreme events. Events like that of

21 August 2014 (with 80 mm in 90 minutes) and, emblematically, that of 1 September 2018 (with an exceptional peak recorded of 142 mm in just 75 minutes) demonstrated the total insufficiency of the urban drainage network. The impermeabilization of the soil, inherited from the intense urban development of the '60s-'70s, makes it impossible to drain such intense volumes of water, causing the network to fail and flooding low-lying urban areas.

Storm Surges are almost invariably associated with intense and persistent Scirocco flows. Their frequency and intensity show an escalation: moving from single events to veritable "sequences" (like the series of June-August-October 2020) that progressively weaken the coast. The apex was reached with the storm of 6-8 December 2020, where the mechanical action of the wind was combined with a peak astronomical tide and, critically, a simultaneous flood wave of the Tagliamento. This dynamic was repeated with the multiple storm surges of autumn 2023 (peak on 2-3 November), which caused extensive damage and demonstrated the now-non-existent resilience of the beach without massive artificial interventions.

Finally, the entire vulnerability framework is exacerbated and amplified by the constant aggravating factor of subsidence. The progressive and documented sinking of the ground (estimated at about 4 mm/year), acting in synergy with eustatism (the rise in mean sea level), reduces the peninsula's already meager altimetric freeboard (Antonioli et al. 2017). This makes every event, whether of pluvial or marine origin, statistically more probable and potentially more destructive.

5.2.5 Public Risk Management: the Main Measures Adopted

Commentato [CM1]: Per Antonella e Matteo: ho inserito questa parte prendendola da un vs allegato e mettendo le tabelle in allegato. Ho tradotto in inglese il vs file ma fate un check. Grazie. C.

Over the last twenty years, the FVG Region and the Municipality of Trieste have updated plans, tools and procedures for the mitigation and management of emergencies (earthquakes, hydraulic/hydrogeological risk, extreme weather events). However, recent events have highlighted operational gaps — particularly in relation to urban drainage, infrastructure maintenance and the integration of urban planning and risk maps — which require targeted and continuous action.

In the Appendix II, a wider description of the law/acts adopted in the FVG UTE as DRM is introduced. Below is a summary of the regulations considered particularly relevant to risk prevention management. The appendix contains a detailed (but not exhaustive) list of the regulations found and analysed.

- **National level:** this includes general provisions on civil protection and emergency management; the principles of planning, coordination and financing of emergency activities.
  - Law 730 of 28/10/1986. Provisions on natural disasters.
  - Law 225 of 24/02/1992. Establishment of the National Civil Protection Service
  - Legislative Decree 1 2/01/2018. Civil Protection Code. Provides the reference framework for emergency prevention, planning and management
  - Decree of the President of the Council of Ministers. 216 1/12/2022. First update of the Flood Risk Management Plan for the Eastern Alps River Basin District
- **Regional level (FVG):** laws and measures defining procedures for hydrogeological and seismic risk, areas of intervention and funding. In recent years, the Region has introduced procedures for integrating the Flood Risk Management Plan (PGRA) into urban planning decisions.
  - Regional Law No. 8 of 18 February 1977. Regulations for the protection of forests from fires
  - Regional Law No. 13 of 18 July 2014. Measures to simplify regional regulations on urban planning and construction, public works, school and public housing construction, mobility, telecommunications and contributory interventions
  - Directive 1939 17/10/2014. Warning system for meteorological, hydrogeological and hydraulic risks.

● **Municipal level (Trieste):** municipal civil protection plans and urban planning variations that incorporate regional guidelines and risk maps (PAI/PGRA). The municipality has also promoted calls for tenders and incentives for private security measures.

○ DGR 99 18/01/2008. Municipal Civil Protection Plan, updated in 2011

○ Trieste Municipal Council Resolution No. 413 — 16 September 2024. Approval of the New Municipal Civil Protection Plan. Operational tool for local emergency management, updated to current risks and coordination procedures with regional structures

○ Council Resolution no. 338/2025. Incentivises preventive measures at the private level, encourages building adaptations and private resilience.

5.3 The Multi-Risk Scenarios in the Naples UTE

5.3.1 The multi-hazard profile of Naples and the 9th Municipality

The map (Figure 34) shows that the municipal territory is affected by multiple overlapping hazards, where hydraulic, landslide, volcanic, and bradyseismic risks intersect with dense settlement patterns and complex infrastructural conditions.

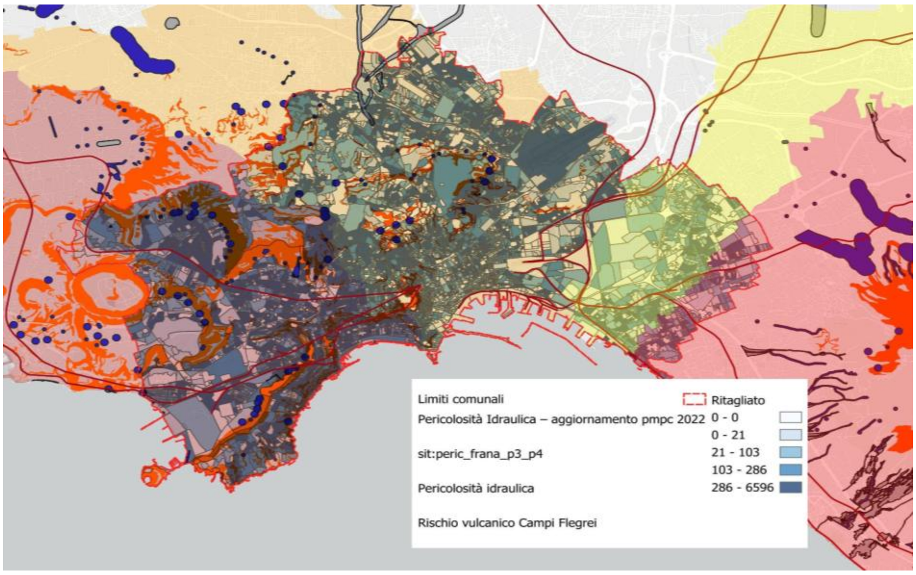

Figure 34: Multi-hazard mapping of Naples

The spatial interaction between these hazards reveals several areas of potential maximum exposure, including:

- the hillsides and slope areas, where landslide-susceptibility zones (P3–P4) and geomorphological instability overlap with dispersed urban expansion;
- the western and north-western sectors, which fall within the volcanic hazard zones associated with the Campi Flegrei and therefore combine urban concentration with high-intensity eruptive scenarios;

- coastal and low-lying areas, where soil sealing, aging drainage systems, and infrastructural discontinuities significantly increase hydraulic vulnerability;
- densely built central sectors, where high settlement pressure amplifies exposure to multiple hazards and reduces the system's capacity to absorb shocks.

The map also highlights localized criticalities, such as the presence of historical landslide areas, hydraulic bottlenecks, and zones structurally exposed to bradyseismic instability. Together, these elements illustrate the complex multi-risk configuration of Naples, where environmental fragilities and urban intensification intersect across the municipal scale.

The following images (Figure 35) provide a graphical synthesis of the environmental events of historical relevance that have affected the city of Naples during the second half of the twentieth century and the past fifteen years.

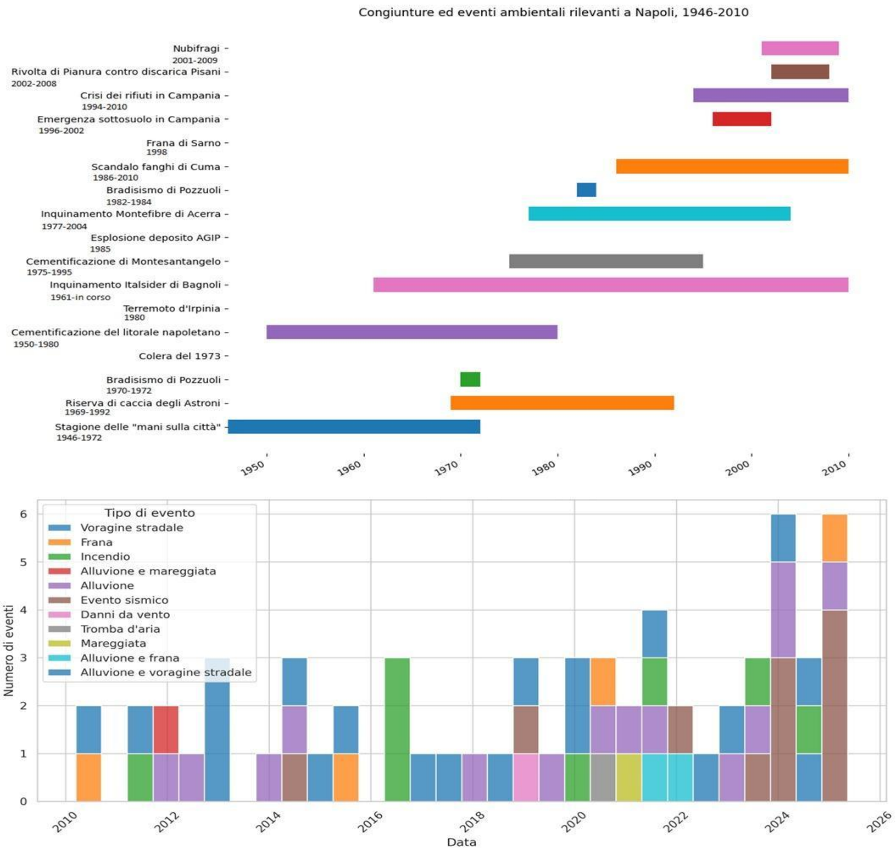

Figure 35: Environmentally significant events in the city of Naples during the second half of the twentieth

Focus on the Ninth Municipality

The Ninth Municipality is located within a complex territorial system characterized by natural elements that define its physical boundaries. To the north rises the Camaldoli ridge, reaching an altitude of 485 meters above sea level, while to the southwest lies the volcanic area of the Phlegraean Fields, which includes several craters—among them those of Pisani and Agnano—now part of a WWF nature reserve.
The inner portion of the territory consists of a volcanic plain, marked by an altimetric gradient descending from the Camaldoli hills toward the central areas, with a minimum elevation of about 50 meters above sea level.
This territorial conformation determines significant hydraulic and geomorphological dynamics: slopes exposed to runoff and shallow landslides during intense rainfall events, and low-lying plains subject to water stagnation and flooding. Moreover, the proximity to the Phlegraean caldera entails exposure to volcanic and bradyseismic phenomena
The analysis aimed to estimate exposure to risk by considering indicators related to:
• building height and number of floors
• base area and volume
• estimated resident population per building

These data were obtained through the integration of altimetric models (DSM and DTM), vector databases, and ISTAT demographic datasets. The resulting geoprocessing operations produced a high-resolution knowledge framework suitable for modelling exposure and multi-risk vulnerability.
This representation supports the identification of the most exposed zones in relation to urban form, settlement intensity, and proximity to essential services.
The constructed spatial layers can be integrated with natural and anthropogenic hazard maps (landslides, floods, bradyseism), enabling the evaluation of:
• the physical exposure of the building stock
• the spatial distribution of the population at risk
• morphological and settlement differences between districts
• criticalities related to isolation, slope gradients, and urban continuity

The adopted approach entails certain uncertainty factors, mainly related to: the resolution of altimetric models (potential errors in estimating building heights); the assumption of a constant floor height (possible discrepancies in historical or public housing typologies); demographic redistribution from census sections; and the absence of volumetric corrections for sloped roofs (not significant for territorial-scale objectives).
Nevertheless, the methodology represents a transparent and replicable model for urban-scale building characterization, functional to the assessment of territorial vulnerability.
The integrated cartographic representation allows the spatial overlap of different identified risk scenarios and the distribution of the resident population within the Ninth Municipality to be visualized (Figure 27).

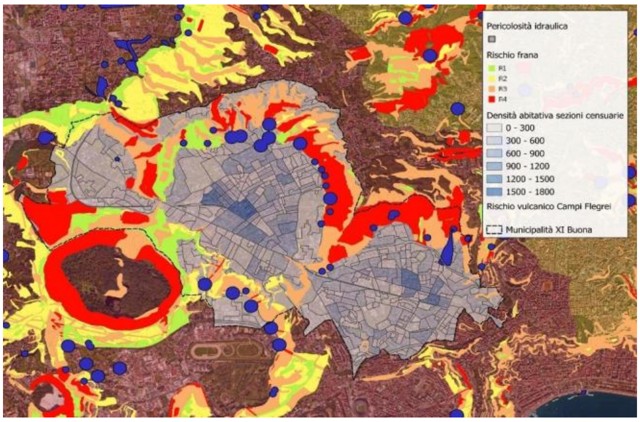

Figure 36: Multi-hazard mapping of the Ninth Municipality

The map shows that the districts of Pianura and Soccavo are both subject to multi-hazard interference, where hydraulic, landslide, bradyseismic, volcanic, fire-related, and climatic risks combine with high settlement pressure.

Areas of higher residential density often coincide with those of potential maximum exposure, including:

• the slopes of the Camaldoli hills, where landslide-risk zones (R3–R4) and recurring wildfires are concentrated;

• the southern sectors of Pianura, located within the red zone of volcanic risk associated with the Phlegraean Fields;

• the peri-urban transition zones, where soil sealing and infrastructural discontinuity increase hydraulic vulnerability;

• the consolidated central areas of Pianura and Soccavo, characterized by high building density and thermal vulnerability during summer periods.

The map also highlights localized critical points, such as areas affected by historical infrastructural collapses (e.g., the Via Campanile sinkhole in Pianura) and the proximity to contaminated sites and disused landfills in the north-western part of Pianura.

Figure 37: the via Campanile sinkhole in 2015, via napolitoday.it

Figure 38: The Pisani landfill in 2007, via it.ejatlas.org 2. The Events.

5.3.2 Historical Review of the Main Events

Historically, the Ninth Municipality has been affected by a range of hydraulic instabilities, minor landslides, seismic and bradyseismic events, wildfires, heat islands, and volcanic and sanitary hazards.

The history of hydraulic risk in the area is long-standing: the first documented floods date back to 1307, followed by others in 1309, 1317, and 1343. The hydraulic vulnerability is linked to the presence of underground cavities and to the natural disorder of the hydrographic system.

Uncontrolled urbanization, which has led to widespread soil sealing, and the chronic sub-standard condition of underground water infrastructure, whose development has not kept pace with urban expansion, have exacerbated these hazards in recent decades.

A particularly emblematic case is the Via Campanile sinkhole (2015) in Pianura, caused by the collapse of a gallery of the Ente Autonomo Volturno due to the subsidence of mud deposits. Four buildings and up to sixty families had to be evacuated. The event was considered preventable, given the clearly inadequate state of the subservices. The instability of the Camaldoli hillside, which looms over both Soccavo and Pianura, represents the main source of landslide hazard. Although slope instability is frequent, major landslide events in Naples are rare; on the Camaldoli hills, landslides are generally superficial and limited in extent (a few hundred meters), unlike catastrophic events such as those in Sarno.

The area also falls within the Phlegraean Fields volcanic complex, subject to seismic risk amplified by bradyseismic activity. The 1980 earthquake was a watershed event—physically, socially, and economically—triggering a radical transformation of both the building fabric and the social composition of the local population, although the damage to structures was largely non-structural.

Bradyseismic episodes (such as the 1983–84 crisis) are continuously monitored but have never historically caused collapses. Between 2008 and 2024, the INGV recorded 24 minor seismic events (below magnitude 1) in the area.

Figure 39: a small house under the Camaldoli hillside, Pianura, photographed during fieldwork

Wildfires—often of deliberate origin—are frequent on the Camaldoli hills, with an average of about 40 per year, peaking during the summer months. Between 2000 and 2003, 152 fires burned over one million square meters of forest. Wildfires are considered preconditioning factors for landslides, particularly when followed by intense rainfall events.

Figure 40: Camaldoli wildfire in 2024, via vesuviolive.it

Vulnerability is further intensified by environmental and urban factors linked to high building density and the limited presence of effective green areas. In Soccavo, numerous thermal vulnerability hot spots are concentrated in zones with low vegetation efficiency (NDVI values below 0.3), poor soil permeability, and high residential density, especially in areas with limited air circulation.

The main cold spot in the area is the Camaldoli ridge; however, heatwaves increase the amount of dry vegetation, thereby raising the risk of fire. In turn, fire acts as a predisposing factor for subsequent landslides and erosion, especially under heavy rainfall, creating a vicious cycle of multi-hazard interaction.

The volcanic hazard in this area is documented in the Civil Protection Plan for the Phlegraean Fields, which includes part of the Municipality of Naples. Specifically, Pianura lies within the red zone of volcanic risk. Current scientific scenarios hypothesize that the next eruption would likely be explosive and of medium intensity, with pyroclastic flows representing the most destructive hazard due to their high speed and ground-hugging trajectory. However, volcanic risk is difficult to quantify, as the last significant eruption (in 1538)

occurred several centuries ago. The area is further complicated by the presence of multiple potential eruptive vents, requiring that emergency planning consider the possible opening of new emission points.
The presence of three landfills—Di.fra.Bi, Comunale, and CITET—in the Pisani area of Pianura represents a major public health risk. All three sites have been affected by sewage and agricultural waste dumping, which are often difficult to detect within the broader metropolitan area.
The Di.fra.Bi landfill, closed in 1996, disposed of toxic, special, and hazardous waste (about 23% of the total) between 1989 and 1993, including hospital waste and chemical materials from the ACNA di Cengio plant. Analyses conducted in 2009 revealed microbiological contamination (fecal coliforms) and chemical pollution (dioxins) in both surface and deep soils. The site is characterized by biogas leaks due to the absence or failure of geomembrane liners.

5.3.5 Losses and Damages

The documentary analysis of available historical sources relevant to historiographic interpretation has made it possible to identify not only the most significant events in the environmental and territorial history of today's Ninth Municipality of Naples but also the related damages and main consequences. Table 6 provides a synthesis of this work:

Date	**Main location**	**Type of event**	**Affected areas (specific)**	**Observed damages, criticalities, and consequences**
1307	N/A	Flood	Probably along the route of Via Antiniana	First documented flood event.
1538	Phlegraean Fields	Volcanic eruption	N/A	Last recorded eruption in the Phlegraean Fields, small- to medium-scale.
1739	Camaldoli	Landslide	Cava di Pianura	Described as a "memorable" event.
1958 – early 1960s	Soccavo	Soil consumption, sealing of valley floors below Camaldoli	Rione Traiano	Hydraulic disorder; structurally sub-standard condition of underground utilities in Rione Traiano.
1961 – 1991	Pianura	Illegal construction	Pianura	7,000 illegal dwellings built in the 1960s; 20,000 in the 1970s; 32,000 in the 1980s. Pianura was the area most affected by demolitions: 25 entire buildings in 1974 and 10 between 1977–79.
1969 – 1987	Astroni	Provincial proposal to convert the crater into a hunting reserve	Astroni Crater	Environmental activism prevented the plan; WWF Campania played a key role in creating the Astroni Oasis (1987).
1970 – 1972 Pozzuoli bradyseism	Phlegraean Fields	Bradyseismic swarm	Pianura and Soccavo	"Mass transfers" of residents from the Phlegraean area into the two districts.

1970 – 1973	Camaldoli	Illegal construction	Camaldoli Hill	252 building violations recorded; the area was designated as public parkland by the Master Plan.
Early 1973	Camaldoli (slope towards Pianura)	Landslides	"Case Vecchie" (Pianura), Via Nazareth, Via Eremo	Slope failures hit two farmhouses; 38 residents evacuated. The event was linked to unauthorized leveling works atop the escarpment.
1974 and 1976	Base of Camaldoli (Soccavo slope)	Unauthorized earthworks	Via Cintia, Via Torre dei Franchi	Illegal construction sites in an area zoned as public parkland; reported by Italia Nostra Napoli.
1975 – 1995	Monte Sant'Angelo, Soccavo	Urbanization / soil consumption	Monte Sant'Angelo, Rione Traiano	Creation of the University of Naples "Federico II" campus instead of the planned public park for Rione Traiano. Remaining green area placed under landscape protection (1995).
1980	Irpinia	Earthquake	Pianura and Soccavo	Construction of new public-housing districts under the *Piano delle Periferie* and the Extraordinary Housing Plan; hydraulic reorganization (e.g. collector in Via Cintia, Soccavo). Massive population relocations and deep socio-economic transformations.
1983 – 1984	Phlegraean Fields	Bradyseism	Pianura district	Establishment of a permanent Civil Protection centre and a seismic-monitoring plan; technical inspections of building stability extended to Pianura.
27 Jul 1996	Camaldoli Hill (Soccavo slope)	Wildfire	15 ha of forest	Preconditioning factor for 90 landslides that occurred between Sept 1996 and Jan 1997.
10 – 11 Jan 1997	Camaldoli Hill (slopes of Soccavo and Pianura)	Hydro-geological crisis / landslides	Camaldoli slopes, Eremo dei Camaldoli	Around 150 landslides; one large slide opened a chasm at the monastery. Severe lack of sewer and aqueduct maintenance; unregulated surface discharges identified. Extraordinary intervention by the Government Commissioner for Underground Emergencies. Post-1997 safety works were found "degraded" in 2013.
Sept 2001	Camaldoli, Soccavo & Pianura	Flood / debris flow	Soccavo and Pianura	167 mm of rain in 4 hours; dozens of cars swept away. Hundreds of potential victims spared because the event occurred at night.
2001 – 2009	Soccavo–Fuorigrotta–Bagnoli	Hydraulic failures / flooding	Arena Sant'Antonio collector, Via Ben Hur, Via Epomeo bridge,	Recurrent events exposing structural vulnerability of the Arena Sant'Antonio collector; the most severe in 2009, with cars dragged by water.

			Circumflegrea bridge	
2000 – 2003	Camaldoli Hill	Recurrent wildfires	Camaldoli Hill	152 fires destroyed over 1.3 million m² of forest; subsequent landslides and erosion.
Late 2007	Pianura	Waste-management crisis / public uprising	Pianura	Violent protests against landfill reopening; urban riots and judicial seizure of the site; long-term health impacts not fully known.
From 2008 onward	Soccavo & Pianura (subsoil)	Minor seismic events	Various locations	24 seismic events (< M 1) recorded, generating public alarm.
2012	Camaldoli	Wildfire	Via Padula	Fire ignited by burning brushwood.
2015	Pianura	Sinkhole / subsoil collapse	Via Campanile & private parks	Caused by the collapse of an EAV tunnel due to mud subsidence; 350 families evacuated. Problem linked to poor-quality subservices.
2015	Camaldoli	Landslide	Via Romano	Triggered by illegal dumping of waste in stream gullies.
2016	Camaldoli slopes (Pianura & Soccavo)	Wildfires	N/A	Likely arson-induced.
2019 & 2024	Camaldoli	Demolitions	Camaldolilli and Camaldoli	Most recent demolitions of illegal buildings on Camaldoli Hill.
2021	Pianura	Cloudburst / mudflow	Viale Grassi, Via Grottole, Via Cannavino, Via Marano Pianura, historic centre	Mudflow reached the town centre. Containment basins built in 1997 had not been maintained and proved ineffective.
Apr 2020, Jul 2022, Aug 2023	Camaldoli	Wildfires	Soccavo slope	Recurrent events, likely of deliberate origin.
Jul – Aug 2023	Pianura	Cloudburst / run-off	Via Cannavino	Road closed 15 days; the Piccola Lourdes containment basin found saturated.
19 Jun 2024	Camaldoli	Wildfire	Soccavo slope, extending to Pianura	Fire approached residential areas and destroyed half the forest cover.
4 Jul 2025	Camaldoli	Wildfire	Pianura slope, upper hill (Bosco)	Flames fuelled by dry vegetation.

Table 6: Summary of the main recorded events and their associated damages

5.3.4 Locally Produced Knowledge

To investigate the locally produced knowledge on environmental risk, the research involved the Churches located within the Ninth Municipality, recognized as key hubs of community life and privileged observatories of local social dynamics. As highlighted during i field explorations, for many inhabitants of the Ninth Municipality, the Church functions as a true social aggregation center that maintains direct an daily contact with the various components of the community. In light of these considerations, four Churches located in different areas of the municipality were identified and involved in the study. Information was gathered through 4 semi-structured, in-person interviews, one of which was choral, for a total of 5 interviewees designed to explore the level of knowledge and awareness of natural and environmental risks in the area.

The analysis reveals a widespread perception of isolation among the neighborhoods of the Ninth Municipality, where residents often feel disconnected from the city of Naples. Interviewees highlight the loss of community identity following post-earthquake relocations and the weakening of traditional networks of belonging. Education emerges as a critical domain, with schools struggling to engage both students and families; in particular, the lack of high schools in the Pianura neighborhood is seen as a factor fueling educational poverty. Despite these challenges, Churches play a key role as community anchors, providing spaces for listening, aggregation, and informal welfare through oratories, educational projects, and participation. Awareness of environmental risks remains limited: while bradyseism and waste issues are recognized, knowledge of evacuation plans and institutional communication is almost absent.

Label	Description	Key Elements	Resources / Tools
Theme 1: Weak territorial belonging	Residents perceive their neighborhoods as separate from each other and detached from the rest of Naples.	“Going to Naples” is an expression used to describe moving toward the city, revealing a symbolic distance and limited identification with the broader urban area.	priests; semi-structured, in-person interviews
Theme 2: Loss of identity	The post-1980 earthquake relocations disrupted community ties, as families from different neighborhoods were rehoused in the same estates.	Progressive loss of local traditions and collective memory.	priests; semi-structured, in-person interviews
Theme 3: Educational fragility	There is a scarcity of secondary schools and limited family engagement.	Few schools and limited parental involvement contribute to low educational attainment and reduced civic awareness of local risks.	priests; semi-structured, in-person interviews
Theme 4: Family vulnerability and youth marginalization	Families are generally young and socio-economically fragile.	Low cultural capital affects children’s schooling and opportunities.	priests; semi-structured, in-person interviews

Table 7: Main findings

The following section summarises the activities carried out to investigate how different groups within the Municipality perceive and interpret environmental risks. Through a combination of semi-structured interviews, risk-perception questionnaires (see Annex III and IV), and urban walks with local residents, it was possible to capture a diverse set of situated insights. These methods revealed how experiences, memories, and everyday spatial practices shape the understanding of hazards across age groups and social contexts, highlighting both generational differences and variations linked to specific places within the neighbourhoods.
In addition, during the urban walks conducted with selected residents, it emerges that seismic events (and even more so bradyseismic ones) need to normalize among older inhabitants, who tend to interpret them as familiar and recurring rather than exceptional. Participants articulated context-based perceptions of risk, recalling past episodes of ground shaking, identifying locations they considered more vulnerable, and highlighting marked generational differences in how hazards are understood, remembered, and incorporated into everyday life.

Label	Description	Key Elements	Resources / Tools
Theme 1: Perception and awareness of environmental risks	The most recognized hazard is seism, followed by issues linked to waste management.	Awareness remains largely experience-based rather than informed by institutional communication.	Semi-structured, in-person interviews
Theme: Perception and awareness of environmental risks among students	The most frequently experienced hazards are heavy rainfall and flooding, followed by seismic events and local fires.	Students exhibit a solid understanding of seismic risk and demonstrate the ability to orient themselves within the neighborhood in the event of a hazardous occurrence.	Risk Perception Questionnaire
Theme: Perception and awareness of environmental risks among residents	The most recognized pattern is the normalization of seismic and bradyseismic events among older residents, who tend to perceive them as “familiar”.	Residents reveal context-based risk perceptions, recalling past seismic and bradyseismic events, identifying places they consider more vulnerable, and showing generational differences in how hazards are understood and normalized.	Urban Walking with local residents

Table 8: Main findings about risk

Across the semi-structured interviews, residents expressed a deeply place-based form of risk perception, shaped by historical memories, everyday experiences, and long-term exposure to seismic and bradyseismic events. Narratives frequently recalled past crises, recurrent floods, and the long-standing environmental legacy of the Pisani landfill, while also highlighting abandoned public facilities, substandard housing, and critical

mobility bottlenecks such as Via Montagna Spaccata. Interviewees linked risks to specific places—landfill areas, flood-prone zones, unstable streets, or evacuation routes—and interpreted them largely through personal experience rather than institutional communication. The conversations further revealed a persistent distrust toward local authorities, rooted in decades of inadequate services, slow emergency responses, infrastructural failures, and unresolved waste issues. Alongside these concerns, cultural landmarks, parish life, local histories, and school-based evacuation practices emerged as key reference points that shape how residents understand and navigate hazards. Overall, risk perception is grounded in memory, spatial familiarity, and a broader sense of institutional fragility, which together contribute to normalizing hazards as part of everyday life.
In relation to students, the most frequently acknowledged hazards are heavy rainfall and flooding, followed by seismic events and small local fires. A mapping exercise and questionnaire conducted with students of Pianura Districts provides a clear picture of how they perceive and navigate their neighbourhood in relation to environmental risks. Their understanding of the district is strongly shaped by habitual routes connecting home, school, and everyday gathering places, while peripheral areas tend to remain less familiar. Open spaces are consistently viewed as the safest locations during emergencies, reflecting a sense of security tied to visibility and the possibility of staying together. Schools, parishes, and other symbolic places function as key reference points, both in daily life and in imagined evacuation scenarios. Students also demonstrate a mature awareness of potential bottlenecks and mobility constraints, recognising how narrow streets or congested routes could hinder evacuation. Overall, their perceptions combine everyday spatial experience with a grounded understanding of the neighbourhood's vulnerabilities.

5.3.5 Public Risk Management: The Main Measures Adopted

Historically, policies have privileged emergency-based repair over prevention, in line with the typical Italian policy style on environmental governance — with a few notable exceptions.

Urban Planning and the Post-Irpinia Earthquake Period
The Piano delle Periferie (Suburbs Plan), developed by the Municipality shortly before the 1980 Irpinia earthquake (Corona, 2007), became instrumental in the post-disaster context. In the Neapolitan suburbs, it enabled the rehabilitation of historic cores of former rural settlements (Picone, 2023).
Law 219/1981 and the Extraordinary Housing Programme provided for the creation of new urban parks, such as the Falcone e Borsellino Park in Pianura (Guida, 2022), and for five new sewer collectors in the area (CIPE, 1988). According to Giovanni Dispoto (int. n. ….), public housing was built in reinforced concrete, in order to make it earthquake-resistant: this knowledge came from Yugoslavia, after the Skopje earthquake, then spread to Friuli, and from there to Naples. However, reinforced concrete might have compromised the gradient of breathability, reinforcing the vulnerability to thermal heatwaves. Additional construction deficiencies were observed, including inadequately ventilated sanitary areas, the use of drywall partitions, and, most notably, improper connections to wastewater systems. Ultimately, the quality of new reinforced-concrete housing built under Law 219/1981 proved poor and many structures were already deteriorated by the late 1990s (Parliamentary Question, 1995). Public oversight of the construction consortia responsible for maintenance - such as Romeo spa - was also insufficient.

Response to the 1983–84 Bradyseismic Crisis
Following the 1983–84 bradyseismic crisis, a permanent Civil Protection center was established in the Phlegraean Fields, and a seismic monitoring plan was drafted. A local scientific committee, coordinated with the National Research Council (CNR) and the Ministry of Civil Protection, was created to process data from the geophysical monitoring network.

Technical checks on the structural stability of buildings were extended to Pianura (Prot. Civile, 1984).

Response to the Subsoil Emergency (1997-2002)
In 1998, the Municipality of Naples approved the "Safeguard Variant" to the General Development Plan, in order to classify areas at risk of landslides, such as the Camaldoli hill, stop any further building, restore hydrogeological balance, consolidate slopes and remove or modify disruptive structures.
At the same time, following the 1997 landslides, a special Government Commission for the Subsoil Emergency was created. After another destructive flood in 2001, a state of natural disaster was declared. Commissioners appointed were mayors Bassolino and later Iervolino.
Major shortcomings emerged regarding maintenance of underground utilities and the widespread presence of illegal connections, exacerbated by fragmented institutional responsibilities and scarce resources among public oversight bodies (La Repubblica, 1997). This coincided with the delayed establishment of River Basin Authorities following the Sarno disaster (1998). A Senate inquiry (2002) - led by members politically opposed to the then city administration - criticized the Commissioner's Office for failing to create a unified authority, misusing EU funds, and not mapping underground utilities and illegal infrastructures.

Evolution of Regional Landscape Planning Schemes
The Regional Landscape Plan (Piano Paesaggistico Regionale, PPR) of the Campania Region is a policy and governance instrument for landscape planning and protection, developed jointly with the Ministry of Culture (MiC). Although the sources examined focus primarily on the recent evolution of the PPR, there are references to earlier landscape governance measures specific to the Camaldoli area. In fact, the Agnano -Camaldoli area had already been subject to a specific Landscape Territorial Plan (Piano Territoriale Paesistico, PTP), approved by Ministerial Decree (DM) on 6 November 1995. The plan was deployed in a context in which the urgency of exercising substitute powers was emphasised, due to the failure of the Campania Region to approve landscape plans or territorial urban plans within the statutory time limits. The emergency measure aimed to ensure effective protection of territories of significant landscape value through preventive and non-deferrable interventions. In fact, the decree highlighted both the danger to the safety of the affected population and the risk of irreversible loss of cultural, architectural, urban, and environmental assets caused by conditions of instability. For example, in the Camaldoli area, the expansion of cemetery areas, as well as the restoration and functional upgrading of the thermal facilities, have been the subject of specific interventions.
Landscape planning tools in Campania subsequently underwent a significant evolution, shifting from emergency instruments to full-fledged planning tools. Article 143 of Legislative Decree No. 42/2004 provided for the transformation of the PTP into a Regional Landscape Plan (PPR), with the objective of recognising the distinctive features of the territory and defining regulations, landscape quality objectives, and guidelines for protection, conservation, and enhancement. The Camaldoli area was incorporated into these more recent planning instruments. Since July 2004, the area was also designated as an integral part of the Metropolitan Park of the Hills of Naples, and as a Site of Community Interest (SCI), as part of the Natura 2000 Network, formally recognised at the European level through the Commission Decision of 19 July 2006, pursuant to Directive 92/43/EEC (the "Habitats Directive"). Finally, on 14 July 2016, the process of co-planning - i.e., the joint preparation of the PPR by the Campania Region and the Ministry of Cultural Heritage and Tourism (later MiC) - was formalised. Regional Government Resolution (DGR) No. 815/2016 established the organisational structure and the need to develop the plan on the basis of operational areas or homogeneous macro-areas.
Another policy instrument in this field was the establishment of the Regional Observatory for Landscape Quality (Osservatorio Regionale per la Qualità del Paesaggio) through Regional Law No. 13/2008, later regulated in 2018 (Regional Government Resolution No. 864/2018). This body was intended to promote studies, analyses, and proposals for the conservation and enhancement of the Campanian landscape, and to define guidelines and criteria for territorial planning and the management of interventions, in coordination with the national observatory.

Focus on the 9th Municipality

Response to Illegal Construction

In the mid-1970s, the Region, Municipality, and judiciary began taking action against unauthorized building, culminating in the highly publicized demolition of a structure in Soccavo, Via Cintia (Il Roma, 1978). The year 1974 saw the highest number of demolitions in the area, with 25 entire buildings torn down (L'Unità, 1974), followed by 10 demolitions between 1977 and 1979 (Il Mattino, 1979). Hundreds of similar measures, however, remained purely formal. The main obstacle was the speed with which developers transferred ownership to private buyers, making confiscation complex. Consequently, for economic and social reasons, the municipality generally imposed only fines on offenders.

In the following decades (1984–1995), Legambiente recorded 17,624 demolition orders in Naples, of which only 595 were executed (3.9%) (Legambiente, 2023).

The repeated use of building amnesties (1985, 1994, 2003) legalized thousands of illegal constructions, including those within protected areas such as the Camaldoli hills. According to ISTAT (2015) estimates, by 2015 there were approximately 35,000 illegal dwellings in the Camaldoli area.

Protection of Public Green Areas

The ecosystem surrounding the Ninth Municipality has witnessed several environmental protection efforts.

Between 1969 and 1987, environmental and civic mobilization successfully opposed the provincial proposal to convert the Astroni crater into a hunting reserve, leading instead to the establishment of the WWF Natural Oasis of Astroni (1987), later recognized under the EU Habitats Directive (1992).

Since 1972, environmental groups have also opposed the urbanization of Monte Sant'Angelo, advocating for a green space for residents of Rione Traiano (Soccavo). Although the University of Naples "Federico II" campus was inaugurated in 1990, the Regional Landscape Plan (1995) imposed landscape protection on the remaining green areas (Caputi, 2022).

From the mid-1970s, citizens and environmentalists lobbied for the creation of a public park on the Camaldoli hills, established in 1980 with funding from the Cassa per il Mezzogiorno. Despite frequent violations of the park's boundaries by illegal construction, the trail network was completed in 1996, and in 2004 management was transferred to the Regional Authority for the Metropolitan Hills Park of Naples. Since 2016, however, the park has fallen into a state of progressive neglect, with poorly maintained coppice woods (Di Gennaro, 2017).

The western slopes of the Camaldoli hills, the green belts near Astroni and Monte Sant'Angelo, and the westernmost agricultural areas of Pianura have been included in the Phlegraean Fields Regional Park, established between 1993 and 2007 (Di Lorenzo, 2006).

Mitigation and Response to the Subsoil Emergency and Recurring Issues

The 1997 subsoil emergency response led to the creation of eight sediment and debris containment basins located midway between the inhabited areas of Pianura and Soccavo and the Camaldoli hills.

Naturalistic stabilization works were also carried out in the Torciolano and Bientola valleys (Saggiomo, 2015). By 2004, four basins were operational, and by 2005, €6.5 million had been allocated for slope consolidation (Parliamentary Question, 2005). Concerning emergency response, the Municipal Councillor for Waste remembers the latest landslide, which happened in 2011, as an exemplary event of recurring issues. At the onset of the event, citizens immediately contacted the Municipality, followed by the Civil Protection, but the latter was practically non-existent in Naples and it had to be deployed from the Province of Caserta. The Civil Protection intended to conduct house-to-house inspections, but were denied access because of illegal dwellings, preventing safety checks. These organisational flaws and social vulnerabilities undermine the efficiency of any mitigation policy, such as the mere construction of containment basins.

The Pisani Landfill Issue

The large-scale popular mobilization of 2007–08, following the Prefect-Commissioner Pansa's proposal to reopen the Di.fra.Bi. landfill, resulted in judicial seizure of the site and prevented its reopening — an outcome perceived locally as a civic victory.

The area was initially designated as a National Interest Site (SIN) in 2008 but was downgraded to a Regional Interest Site (SIR) in 2013, which froze remediation funds and halted environmental characterization work, despite no improvement in environmental conditions. The criminal complaint for negligent epidemic was dismissed due to the absence of a municipal or regional epidemiological registry capable of establishing a causal link between the landfill and cancer incidence (Armiero & Iengo, 2017). Giovanni Dispoto (int. n.), in the late Nineties proposed creating a golf course, a proposal that was accepted, but there was a landscape protection constraint (Law 1495) affecting the section located in the Municipality of Pozzuoli. The purpose of the constraint was to integrally restore the ecosystem, which was impossible because of the high levels of pollution. The current Municipal Councillor for Waste hopes that the sealing of pollutants (a 'safety measure' for immediate mitigation and as an alternative to 'integral restoration', according to the Italian Environmental Code) will be chosen as a definitive option.

Ongoing (and Completed) Projects Across All Phases of the Disaster Risk Management (DRM) Cycle

Seismic, Bradyseismic, and Volcanic Risk

The Municipal Administration and the National Civil Protection Department have launched public awareness campaigns on seismic and volcanic risks, including evacuation drills in schools—though participation levels remain limited. Local authorities acknowledge the need to significantly strengthen communication and public engagement in risk preparedness.

Regional Wildfire Prevention Plans

Wildland fire prevention and management plans (Piani AIB) in the Campania Region are rooted in national legislation, in particular Law No. 353 of 21 November 2000 (the "Framework Law on Forest Fires"). This national framework requires Regions to adopt an annual planning document for forecasting, prevention, and active firefighting activities. The Campania Region implemented this requirement through Regional Government Resolution No. 2246 of 7 June 2002.

In Campania, the periodic updates of the AIB Plans (such as the 2019-2021, 2021-2023, 2022-2024 and 2023-2025 plans) have been developed through a participatory model, involving the organisation of "Technical Working Tables" and consultations with all relevant institutional actors (Carabinieri Forestali, National Fire and Rescue Service, Parks Authorities, Civil Protection, Mountain Communities, and SMA Campania). Critical wildfire seasons (such as 2017 and 2021) further highlighted the need to strengthen an integrated approach and overall response capacity. In particular, the measures implemented focused primarily on reducing response times in order to limit burned areas (in fact in 2022 all provinces recorded a clear improvement compared to previous periods).

A second line of action concerned the strengthening of technological tools, training activities, and volunteer capacity: first, in 2019, the SMA Campania mobile app was redesigned to facilitate the reporting of fires by citizens and operators to the Operations Room and to support navigation to incident locations; second, to increase the number of ground operational teams- especially in the context of a shortage of DOS (Directors of Firefighting Operations) - the Region established the "Campania Region A.I.B. Volunteer Teams," which may also operate in high-risk areas (Regional Government Resolution No. 464 of 27/10/2021); third, an extensive training programme for new DOS was launched for personnel from delegated authorities and volunteers, including the use of the Forest Fire Area Simulator (FFAS), carried out in cooperation with the Carabinieri Forestali; fourth, the Decision Support System (DSS), in use since 2009 and continuously evolving, was enhanced to support wildfire event management, data storage, and statistical processing.

Finally, awareness-raising activities were carried out targeting mayors, encouraging them to update their municipal civil protection plans, as recommended since OPCM 3606/2007, for the management of wildland-urban interface fire risk.

Focus of the 9th Municipality

Camaldoli Hill Wildfires: Prevention and Response

A turning point came with the issuance of the Prime Minister's Ordinance No. 3606 of 28 August 2007, following a severe resurgence of wildfires, which introduced the obligation for municipalities to prepare emergency plans specifically addressing the risk of wildland-urban interface fires. The Camaldoli area is considered a typical example of a highly vulnerable interface zone; therefore, several policies implemented there were those specifically designed for the management of interface areas, applied at the local level.

Over the past decade, during the summer season, the Campania Region has issued Director's Decrees declaring a state of severe wildfire danger (e.g., Director's Decree of 4 July 2017, 12 June 2023, 10 June 2025). In parallel, municipal emergency ordinances have imposed obligations and prohibitions related to prevention and maintenance activities, such as a ban on burning vegetal residues; and the obligation to clear the area surrounding settlements within a radius of at least 20 metres, by cutting herbaceous and shrub vegetation.

In addition, policies relevant to areas such as Camaldoli - characterised by wildland-urban interface ris - have focused on prevention and on coordinated response measures combining regional planning with specific local interventions. For example, within the framework of the Programme Agreement with SMA Campania, targeted clearing operations were planned for this area.

However, the 2024 data confirmed the criticality of the area. In June 2024 alone, 13 wildfires were recorded in Naples, affecting 14.56 hectares, with the most severe event occurring in the Soccavo - Pianura area (Via Cantieri). The operational response deployed on 20/06/2024 involved a coordinated system including AIB volunteer teams, SMA Campania personnel, and the National Fire and Rescue Service, all directed by the Civil Protection Operations Room: approximately 100 operators and 3 aerial assets were mobilised to contain the flames on both sides of the affected area.

In 2020, SMA Campania created a firebreak line on the Pianura slope of the Camaldoli hills, designed to be cleared and renewed annually as part of regional wildfire prevention measures.

Flood and Landslide Mitigation and Rehabilitation of Underground Utilities

In 2021 the major and most recent flood happened and it involved a debris flow from the Camaldoli hill to the centre of Pianura. The state of emergency lasted for a couple months, according to the President of the IX Municipality. Following the flood, it was found that the four existing sediment-containment basins were filled with solidified mud and therefore ineffective due to lack of routine maintenance and unclear division of responsibilities. Consequently, administrative management was transferred to the Integrated Municipal Water Service, which now outsources annual maintenance of the four active basins with a budget allocation of €100,000 per year, as confirmed by representatives of the Ninth Municipality. The remaining four basins are currently abandoned. Since the 1997 hydrogeological emergency, efforts were initiated to establish a database of underground cavities, which, according to Domenico Calcaterra, may have informed more recent 3D mapping projects of Naples' subsoil, such as the Smart City 3D project (Municipality / ISPRA / University of Naples), active since 2024. Following the 2015 Via Campanile sinkhole, according to Ninth Municipality officials, the old unauthorized water network in the area was channeled and decommissioned. Additionally, works are underway for the completion of the Zoffritto channel in Pianura, aimed at mitigating hydraulic risk.

The Pisani Landfill

Despite the downgrading of the Pisani landfill area from National Interest Site (SIN) to Regional Interest Site (SIR), in 2015 funds were allocated for the characterization and subsequent remediation of the contaminated sites in Pianura. However, local residents are still waiting for the works to begin. According to the current Municipal Councillor for Waste, efforts are ongoing to secure regional attention and ensure the safety and stabilization of the landfill sites.

Management of the Arena Sant'Antonio Basin

The Arena Sant'Antonio is the main drainage collector for Naples' western area. Originally a natural watercourse, it transported solid material from the Camaldoli hill to the Gulf of Bagnoli, maintaining coastal equilibrium. Since the 1980s, the channel has been running freely, but in an unsanitary way, and subject to urbanization pressures. Hydrogeological analysis reveals buried channels and backfills in Soccavo and Fuorigrotta, altering groundwater flow. During heavy rain, these buried impluvia act as collectors, causing localized collapses and sewer overflow (Saggiomo, 2015). Illegal construction worsens hydraulic vulnerability. An SMS alert system for flood risk never worked properly, according to the current Municipal councilor for Waste. Works are ongoing on the Arena Sant'Antonio's connected channels, but their completion depends on regional authorisations and funding deadlines. Currently, flooding risk persists at critical points (e.g., Via Epomeo flyover), despite the presence of containment basins.

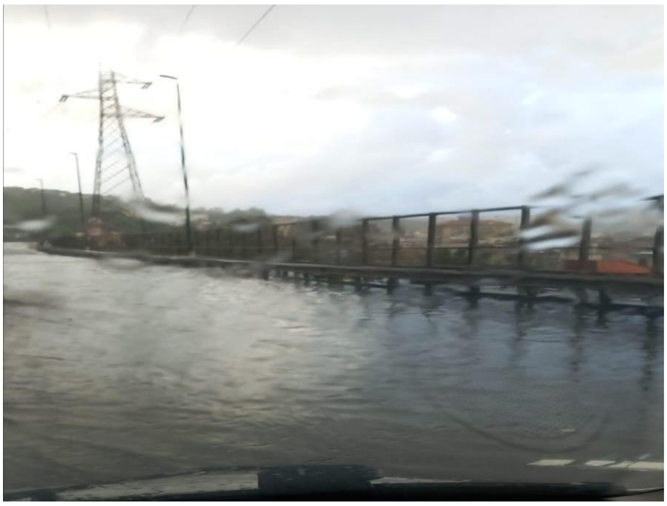

Figure 40: a flood at the Via Epomeo flyover, 2023.

Escape Routes from Pianura

The current President of the IX Municipality acknowledged the current insufficiency of possible escape routes from Pianura, in case of emergency. There are only two of them: Via Montagna Spaccata and Via Sartania. The road surface of Via Montagna Spaccata is currently under upgrade, particularly the section leading to Quarto and Pozzuoli (€1 million), funded by Neapolitan Municipal resources. A viaduct over Via Sartania has recently been built by the regional authority.

Urban Planning

Since 2008, a “Building Conversion Program” has been underway in the IX Municipality, providing for the replacement of deteriorated housing units with eco-architecture structures and the overall redevelopment of the districts through a neighborhood contract.
The intervention in the Pianura district covers an area of approximately 85,000 m² and includes the replacement of 605 housing units, with an overall investment of about €58 million. In addition to the reconstruction—carried out through traditional building techniques integrated with bio-architecture—the program foresees a comprehensive redesign of public spaces, the reconfiguration of the pedestrian network and green areas, and the creation of new spaces for social interaction, leisure, and commercial activities. The first implementation phase has involved two “trigger areas,” where new residential buildings have been developed in Via Cannavino as part of the initial substitution phase. Further construction phases are planned, including an additional 90 units and the progressive demolition of the most deteriorated housing blocks.
The intervention in the Soccavo district concerns an area of approximately 69,000 m² and provides for the replacement of 410 housing units, with an investment of about €38.5 million. Similar to Pianura, the project integrates traditional construction with bio-architecture and includes the redesign of vehicular and pedestrian spaces, green systems, and areas dedicated to social aggregation, leisure, and commercial uses. The first “trigger areas” are currently under construction, with the development of 46 new dwellings located near Via Croce di Piperno: local inhabitants will be moved from their former homes in Via Palazziello (an area located right under the Camaldoli hillside and classified as R4 for hydrogeological vulnerability). A subsequent phase—already approved—will involve the construction of an additional 90 housing units and the demolition of the first set of existing buildings as part of the structured replacement program.

Figure 41: Via Palazziello (left) residents will be moved in Via Croce di Piperno (right)

Green Area Protection

The Selva di Pianura, a key green area located between the Camaldoli hills and the residential district—serving as a potential ecological buffer—is currently in a state of neglect. However, local associations such as Oceanus and ZappaSocial are actively promoting its rehabilitation and community reactivation.

Conclusion: Understanding, government, learning: fields in interaction towards an intersectoral approach

Urban systems are not only made up of technical infrastructure but also cultural infrastructure – to use a term that echoes the former – understood as models of relationship and interaction that guide the framing of the issue to be addressed and, consequently, impact operational decisions as well as the outputs and outcomes of the actions taken. This implies that cultural infrastructure, in a broad sense, is relevant to DRR and CCA.

Cultural infrastructure is a long-term outcome of the specific context of reference and is linked to events of various kinds that have taken place within the community, to the specific characteristics of the economic groups in the area, and to the socio-political resources and traditions of the social fabric. This is an extremely complex intertwining, specific to each urban or metropolitan reality, with a partial but noticeable dynamism and, therefore, mostly elusive to attempts at typification. The embeddedness of cultural infrastructures in social contexts requires the use of bottom-up approaches to grasp the possible link with DRR strategies. In an attempt to promote an intersectoral and interdisciplinary approach in the modelling of RV1 and RV2, it is possible to propose a working framework that moves towards the identification of certain factors with a certain degree of typification.

Firstly, the meaning of cultural infrastructure in the context of DRR was defined by referring to the Sendai Framework (in particular in relation to Priorities 1, 2 and 4 respectively: Understanding Disaster Risk, Strengthening disaster risk governance to manage disaster risk and Enhancing disaster preparedness for effective response) and to SDG (in particular in relation to Goal 11 – Sustainable cities and communities). This led to the identification of three fields of action (Table XXX).

In order to contribute to the PoC on which Returnville is based, three Territorial Processing Units (TPUs) were identified in which to conduct the analysis. The TPUs were selected according to the following criteria: a) different territorial and administrative extent, b) different risk scenarios, c) different socio-demographic, socio-economic and socio-political characteristics. The lack of homogeneity is explicitly aimed at facilitating the identification of variables whose salience may be independent of the differences between the territories. The following were selected: 1) Genoa, 2) the IX Municipality of Naples (Soccavo and Pianura districts), 3) the Friuli Venezia Giulia coastline: Trieste, Lignano, Grado and Monfalcone.

Within each TPU, mixed techniques were used to identify the specific characteristics of the three fields of action described below and the forms of interaction between them. The material collected is currently being processed in order to investigate the hypothesis that there are appreciable correlations, interactions or connections between specific configurations of the three fields of action and DRR models. The outcome of this analysis is aimed at populating RV1 and RV2, also in order to hypothesise and simulate intervention scenarios in light of the characteristics of the three fields of action and the ecosystem they generate. This would help to identify the possibilities for implementing certain actions rather than others, or to establish whether or not the action is compatible with the system of relationships defined by the actors in the three fields of action.

Field of action	Action	Actor
Risk understanding	Updating, extending and deepening scientific knowledge relating to natural hazards through scientific research	A group of collective actors, formalised and with recognised scientific expertise, present and active (e.g. university research groups, public and private research institutes).
Risk government	Development of strategies aimed at prevention, intervention and reconstruction through the adoption of administrative measures with regulatory content.	A group of collective and individual actors with formal responsibilities and legitimate decision-making powers (e.g. municipal councillors responsible for civil protection, municipal officials and technicians, mayors, civil protection area managers).
Risk learning	Updating, disseminating and consolidating the culture of vulnerability by involving the population in a broad or targeted manner to specific segments.	A group of collective (and individual) actors, formalised and with recognised authority, and active (e.g. local associations active in the field of civil protection, institutional actors such as the Chamber of Commerce, workers' and employers' associations).

Table 9: Fields of action

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