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Fostering climate change adaptation through local authority efforts: Insights from the case study of Genoa

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ABSTRACT

In recent years, the adaptation of local communities to climate change has become a key priority for policymakers. Local authorities, especially in urban areas, play a crucial role in implementing adaptation policies to reduce climate-related risks. In this study, we investigated the development of local adaptation processes in the area of Genoa, Italy, owing to its vulnerability and exposure to risks that are expected to worsen in the near future. In particular, we investigated the contribution of the regional, metropolitan, and municipal levels to local adaptation, thus identifying which local authority exerts the maximum effort throughout the planning, implementation, and monitoring phases. The analysis applied the UAST (Urban Adaptation Support Tool) as a methodological framework. The results showed that achievement of a strong connection among institutional levels, especially in terms of knowledge sharing and stakeholder involvement, can significantly enhance adaptation outcomes. Conversely, when an integrated approach among local authorities becomes flawed, the responsibility of implementing adaptation is unevenly distributed among the concerned actors, and municipalities might play a major role. In particular, we identified six main constraining factors that undermine local adaptation processes: i. Lack of mandatory adaptation commitments at the sub-national levels; ii. Mismatched timeframes of governments mandate and adaptation processes; iii. Delayed approval of a plan at the national level; iv. Complexity of the multilevel policy framework; v. Complex variety of available policy tools; vi. Lack of control, steering, and systematization of adaptation measures. Accordingly, we close this study with some policy recommendations intended to foster the efficacy of local adaptation.

1. Introduction

The effects of climate change are increasingly apparent, hence urgent countermeasures must be implemented. Moreover, fostering the adaptation of human communities to these unavoidable changes must become a key priority (IPCC et al., 2022). Although such a resolution needs to be embraced as a shared endeavor (Biesbroek et al., 2009; Huitema et al., 2016), local governments are especially recognized as playing a pivotal role (Heidrich et al., 2016; Huitema et al., 2016; Reckien et al., 2018; Trentanovi et al., 2021), possibly as pioneers of local transformation (Amundsen et al., 2018). This is due to their crucial position at the interface of local climate

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List of abbreviations

UAST -	Urban Adaptation Support Tool
NUTS -	European Nomenclature of territorial units for statistics
LAU -	Local Administrative Units
RSSD -	Regional Strategy for Sustainable Development
RSACC -	Regional Strategy for Adaptation to Climate Change
SECAP -	Sustainable Energy and Climate Action Plan
CRiAMOPA -	Competenze e Reti per l'Integrazione Ambientale e per il Miglioramento delle Organizzazioni della Pubblica Amministrazione (Expertise and networks for environmental integration and improvement of public administration)

impacts; the concatenation of strategies, plans, and norms; and the actual implementation of designed actions (Heidrich et al., 2016; Measham et al., 2011). In brief, local governments are the closest to the places and communities affected by climate impacts (Amundsen et al., 2018), hence they have a deeper understanding of local adaptation needs, as well as direct responsibility and authority on the implementation of policies (Bonnett and Birchall, 2023; Guyadeen et al., 2019; Nicolletti et al., 2020). Nevertheless, there is still room to explore the extent to which local governments can and want to engage in these processes, as well as the effect of higher-level support (Bonnett and Birchall, 2023; Measham et al., 2011; Pietrapertosa et al., 2021; Reckien et al., 2018; Salvia et al., 2024). Indeed, local governments are starting to address the challenge of local adaptation, often encouraged and aided by external support, such as that provided by international networks and initiatives (Aboagye and Sharifi, 2024; Reckien et al., 2018) or regional-level authorities (Bonnett and Birchall, 2023; Pietrapertosa et al., 2021).

Consequently, following and assessing the adaptation processes unfolding at the local level has increasingly garnered attention (Araos et al., 2016; Olazabal et al., 2019). Indeed, evaluating the enacted adaptation strategies, plans, and actions would be crucial to verify if they actually reduce local vulnerabilities and increase resilience (Berrang-Ford et al., 2019, 2021; Olazabal et al., 2019), also in light of the mandates of the latest international agreements (Ford et al., 2015; Lesnikowski et al., 2016). In particular, it is fundamental to incorporate a preliminary investigation on the local conditions of vulnerability (Prall et al., 2023), as well as on the local impacts of climate change and the related risks (Preston et al., 2011) to build a sound adaptation process and tailor the appropriate governing tool. Notably, careful selection and implementation of the adaptation options (Lesnikowski et al., 2016), including evaluations of the available resources, is crucial to curb undermining issues such as limited assets or local support (Preston et al., 2011). Moreover, monitoring and evaluation is another component of paramount importance in the adaptation process, since it provides relevant insights on the timely adjustment and enhancement of the envisioned adaptation tools (Haasnoot et al., 2018). In this regard, it is also suggested that a strong connection among governing levels and local stakeholders is fundamental to building a successful adaptation pathway (Haasnoot et al., 2018), and significant effort should be made to integrate the adaptation measures with the existing policy framework (Preston et al., 2011; Olazabal and De Gopegui, 2021). However, it appears that the adaptation progress, related effectiveness, and reporting stages are highly variable among cities (Araos et al., 2016; Reckien et al., 2018). Under these conditions, the role of local governance becomes crucial, as poor adaptation planning is widely recognized as a primary cause of increased vulnerability, both within and beyond the boundaries of the area (Adger et al., 2005; Schipper, 2020).

Notably, the local adaptation process has been investigated on different aspects. For instance, several studies evaluated local adaptation plans across broad contexts such as the European one (Reckien et al., 2014; Kona et al., 2018) or the international one (Aboagye and Sharifi, 2024). In addition, other studies identified what can motivate or limit the development of local plans (Measham et al., 2011; Reckien et al., 2015; Archie et al., 2018), even stemming from other governing levels (Heidrich et al., 2016). In other cases, the research concerned more technical issues, for instance providing a framework to track adaptation processes (Berrang-Ford et al., 2019) or to support the identification of effective adaptation measures (Coelho et al., 2020), or rather focusing on the cost-benefit analysis related to such measures (Markanday et al., 2019). Concerning the research methodology, most studies adopt a horizontal approach, mainly comparing similar levels of government, e.g. cities, that hardly traces the vertical interactions among governing levels shaping the local adaptation process. Hence, as the vertical approach of analysis remains understudied, we deemed it relevant to further explore it on a case-study basis.

Accordingly, the objective of this study is to assess the contribution of each governing level, and identify which level made the main adaptation effort. We focused on the local levels: regional, metropolitan, and municipal, as it is fundamental to verify if some authorities contribute excessively compared to the respective available resources. To this end, this study focuses on the area of Genoa, Italy, a vulnerable territory highly exposed to climate-related hazards. To our knowledge this is one of the first investigations on local adaptation processes in Italy adopting a vertical perspective to eventually verify on which level of government relies the main adaptation effort.

A qualitative, in depth, plan content analysis was designed, following the framework of the Urban Adaptation Support Tool (UAST), as designed by the European Commission specifically for local adaptation processes (European Commission and European Environmental Agency n.a.a); also, the context of Genoa was clarified (Section 2 Material and methods). Next, the contribution of the governing levels to the adaptation process was analyzed (Section 3 Results). Finally, based on the findings, some relevant insights and general remarks were gathered (Sections 4 Discussion and 5 Conclusion).

2. Material and methods

In order to evaluate the contribution of the local multi-level governance to the adaptation process occurring in Genoa, we performed a qualitative analysis according to the approach of the plan content analysis (Bonnett and Birchall, 2023; Guyadeen et al., 2019). In particular, we evaluated the content of the most relevant policy documents against rigorous parameters that we derived from the framework set by the UAST. Notably, among the methodological approaches available in the literature concerning the development of adaptation policies (see EEA, 2018; EEA, 2020; Ebrey et al., 2021; European Commission, 2018a; European Commission, 2018b), we referred to the UAST, developed and proposed by the European Commission to guide local adaptation processes and thus promoted in the Climate-Adapt platform (EC and EEA, n.a.a). Although further details are discussed in the following paragraph, it is interesting to observe here that one of the main assets of the UAST is defining some macro-areas around which the adaptation process must revolve. In other words, the UAST sets a relevant and reliable framework to understand local adaptation processes and as such we assumed those macro-areas to guide the qualitative, in-depth analysis of the documents outlining the multi-level adaptation process in the area of Genoa, with the additional direct contribution of informed stakeholders.

2.1. Methods used

We performed an in-depth, qualitative analysis of the available documents concerning climate change adaptation at the regional, metropolitan, and municipal levels for the area of Genoa. Commonly known as plan content analysis, this approach is gaining momentum due to the urgency of assessing the efficacy of climate policies (Bonnett and Birchall, 2023; Guyadeen et al., 2019). In particular, the plan content analysis assesses the quality of policy documents against a rigorous set of parameters. In this case, we analyzed the pertinent climate policies systematically categorizing and organizing the relevant content against the framework set by the UAST for local adaptation. In brief, we assessed if and how the documents contributed to the macro-areas (or steps, as described in the following section 2.2) that the UAST outlines as fundamental for an effective local adaptation process. Hence, each document was evaluated based on its specific contribution to local governance and its capacity to address the territory's climate vulnerabilities.

Accordingly, the initial activity centred on scoping through all the available policy documents that deal or mention climate planning and action at the regional, metropolitan and municipal level; following, we selected the pertinent policy documents for this analysis. In Italy the land planning system is based on a complex framework that includes both traditional regulatory planning instruments, such as municipal zoning plans, and strategic planning instruments, such as the Sustainable Energy and Climate Action Plan (SECAP). It is relevant to observe that these two instruments are inherently complementary and interlinked with each other. Regulatory instruments are binding and prescriptive, defining specific rules for land use and regulating aspects such as urban zoning, construction, and infrastructure. Strategic instruments are not binding but provide guidelines and recommendations that are expected to be incorporated into other regulatory instruments to become effective. Notably, they focus primarily on long-term objectives, such as climate change mitigation and adaptation, promoting thorough processes that increase local resilience.

Given this distinction, the present research focuses on strategic planning instruments, specifically those that address climate adaptation challenges and, although non-mandatory, play a central role in promoting innovative and voluntary policies to enhance local climate resilience. We argue that the selected strategic planning documents convey the approach and vision of the area towards the climate issues in the most coherent and comprehensive way. Indeed, all the scoped documents somehow contribute to climate governance but with limited or minor references. Conversely, the selected strategic planning documents represent a coherent, broad and consistent set of intentions, objectives, assessments, and measures to tackle climate adaptation.

As such, our analysis avails of a combination of primary policy documents, including climate strategies, plans, and technical reports. The core documents of our study are:

- The Regional Strategy for Adaptation to Climate Change (RSACC) (regional level);
- The Metropolitan Strategic Plan (metropolitan level);
- The Sustainable Energy and Climate Action Plan (municipal level);
- The Genoa Lighthouse 2050 (municipal level).

Notably, we also went through the European adaptation strategy, and the Italian adaptation strategy and plan (for some mentions, see Sections 3.1 and 4.2). However, due to their descriptive nature, focused on providing guidelines and recommendations, we assumed such European and national policies not pertinent enough for the main in-depth analysis of this study, centering on the adaptation at the local level. Furthermore, to complement and clarify the collected information and published documents, we availed the knowledge directly gathered by one of the authors, who participated in the policymaking processes. Insights were gained from their attendance at workshops, urban and regional planning sessions, and public events. The core documents and the most relevant policymaking events for this research are presented in Appendix A (Tables A.1 and A.2, respectively).

2.2. The analytical framework

Once the policy documents were selected, we could set the parameters for the plan content analysis. In this case, we referred to the UAST, that is a tool to frame and guide local authorities during the process of designing, enacting and monitoring adaptation policies and measures; as such, the UAST is a downscaled version of the EU adaptation scoreboard methodology (European Environmental Agency, 2018 pp. 155–170), developed by the European Commission to support adaptation processes mainly at the national level (EC

and EEA, n.a.a). Though relatively recent, the UAST has effectively supported the development and tailoring of climate adaptation frameworks to specific study areas (Coelho et al., 2020) or was further integrated in decision-support systems, such as those focused on climate information (de Wit et al., 2020) or the management of local risks and vulnerabilities (Lindner et al., 2021).

The UAST comprises 6 steps, further divided into 27 sub-steps, which follow the overall adaptation process employed by local governments (Table 1).

Notably, we considered it particularly relevant that the UAST recalls the adaptation policy cycle (EEA, 2020), as a reminder of the commitment to a continuous revision and improvement of plans and measures based on evidence of their effectiveness (EC and EEA, n. a.b) (Fig. 1).

Step 1 of the framework includes the preparatory activities aimed at gathering information from and engaging with both political and local stakeholders. Next, step 2 suggests evaluating the area in terms of past, present, and expected climate-related impacts, vulnerabilities, and risks, which is intended as a reference for prioritizing objectives. In this context, step 3 requires the collection and evaluation of the best available adaptation options to identify, in step 4, the most suitable options considering the local characteristics. Step 5 indicates the design of appropriate adaptation measures, their incorporation in relevant policies, and eventual implementation, while also accounting for mitigation measures. Finally, step 6 requires the continuous revision of the adaptation process.

2.3. The study area

We introduce here the main characteristics of the area of Genoa, in order to better contextualize the considerations that will follow in the results and discussions. In particular, the Liguria region lies on the western side of northern Italy, facing the Ligurian Sea, a sub-basin of the Mediterranean Sea. The region shows a complex and varied topography; it forms an arc of mountainous and hilly territory characterized by a mild climate due to its proximity to a particularly deep sea (approximately 1000–1500 m), and the shelter from the cold northern winds provided by the Alps and Apennines. These two mountain chains run parallel to and generally at a short distance from the coast, in a diagonal direction from SW to NE on the western side (“Ponente” area) and WNW to ESE on the eastern side (“Levante” area). This orographic structure leads to significant climatic differences not only between the coast and the hinterland, but also between the eastern and western areas.

The city of Genoa is situated in an almost central position within the Ligurian territory (Fig. 2). It is an ancient, pre-Roman settlement, which became an important maritime republic in the Middle Ages. The city has experienced major urban development over the last century, and today Genoa hosts one of the 10 most important European harbors for trade routes between Northern Europe and the Mediterranean Sea (Acquaotta et al., 2018).

The intense anthropization of the Genoa area collided with the typical local geomorphological and environmental components of a coastal mountain system, especially the numerous steep and short watercourses with very short concentration times during floods

Table 1

The analytical framework used to investigate the adaptation process in the Genoa area, based on the Urban Adaptation Support Tool. Source: Authors' elaboration.

Urban Adaptation Support Tool	
Step	Sub-step
1 Preparing the ground for adaptation	1.1 Obtaining political support for adaptation 1.2 Collecting initial information 1.3 Setting up adaptation processes within and beyond the municipality 1.4 Identifying and obtaining human and technical resources 1.5 Identifying and obtaining financing and funding 1.6 Identifying and engaging stakeholders 1.7 Communicating adaptation to different target audiences 1.8 Finding additional support
2 Assessing climate change risks and vulnerabilities	2.1 Recognizing past and present climate impacts 2.2 Understanding climate projections and future impacts 2.3 Identifying vulnerable urban sectors 2.4 Conducting risk and vulnerability assessments 2.5 Understanding the role of surrounding areas in adaptation 2.6 Identifying main adaptation concerns and defining objectives
3 Identifying adaptation options	3.1 Creating a catalog of relevant adaptation options 3.2 Finding examples of good adaptation practices
4 Assessing and selecting adaptation options	4.1 Choosing an assessment framework for adaptation options 4.2 Conducting a cost-benefit analysis of adaptation measures 4.3 Prioritizing adaptation options
5 Implementing adaptation	5.1 Designing an effective adaptation action plan 5.2 Finding examples of adaptation action plans 5.3 Mainstreaming adaptation in urban policies and plans 5.4 Addressing climate change through adaptation and mitigation
6 Monitoring and evaluating adaptation	6.1 Developing the monitoring and evaluation approach 6.2 Defining monitoring indicators 6.3 Finding examples of adaptation monitoring indicators 6.4 Using monitoring results to enhance the process of adaptation

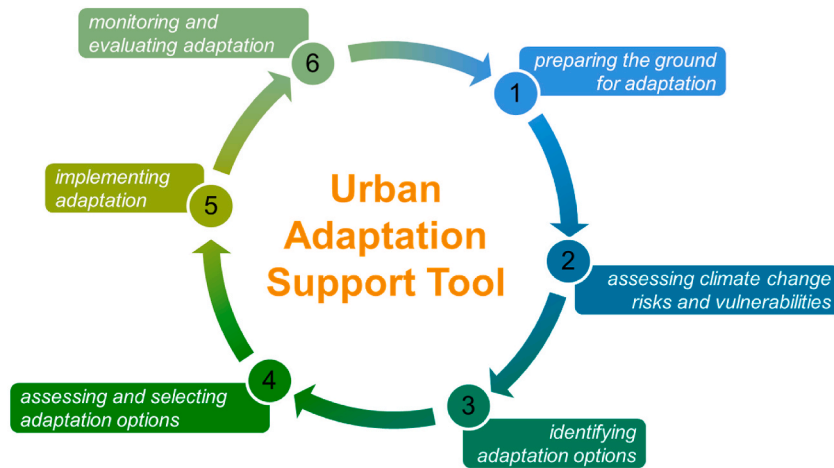


Fig. 1. Visualization of the policy cycle of the Urban Adaptation Support Tool. Source: Authors' elaboration.

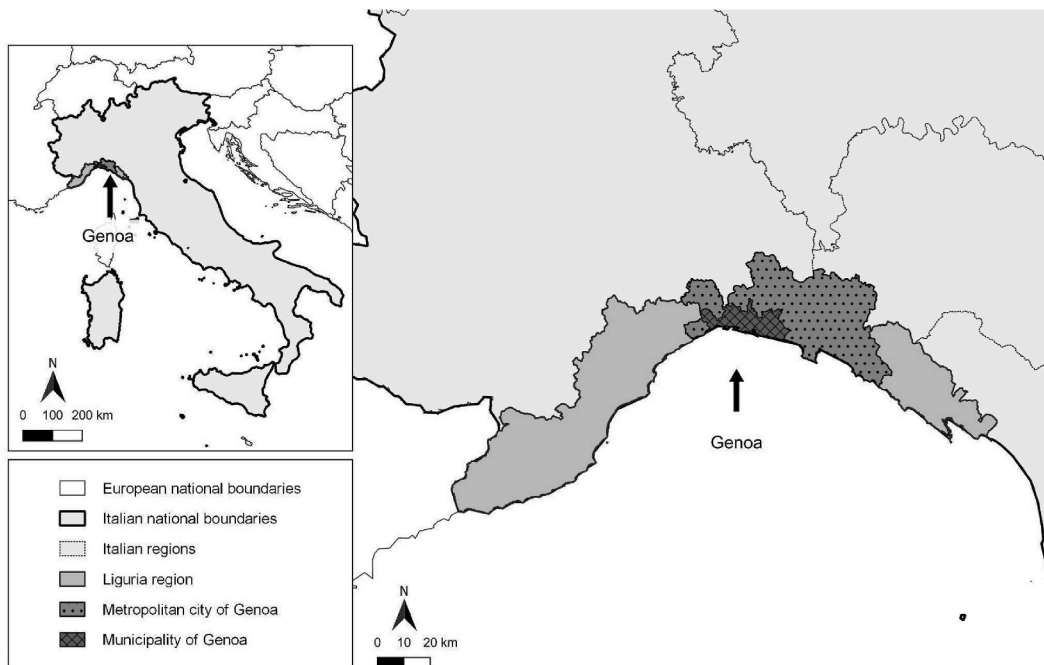


Fig. 2. Localization of the Liguria region, the Metropolitan City of Genoa, and the Municipality of Genoa within the Italian and European national borders. Source: Authors' elaboration.

(Acquaotta et al., 2018). In particular, the mountainous terrain close to the coast limits expansion, concentrating most settlements in the lower altitudinal zones (0–299 m above sea level).

The two most important catchments for Genoa are the Polcevera Stream, which is the largest and most populous basin located west of the port, and the Bisagno Stream flowing east of it (Fig. 3). Notably, especially in late summer and autumn, the Ligurian Gulf is characterized by extreme rainfall events, affected by the local geomorphology (Silvestro et al., 2016; Acquaotta et al., 2018). The high intensity and frequency of these phenomena, the worsened conditions caused by the progressive and chaotic urbanization together with the structural modifications of riverbeds (see e.g. the widespread culverted urban river beds), and consequent geo-hydrological risk have made Genoa a case of international interest (Brandolini and Sbardella, 2001; Hally et al., 2015; Harpham et al., 2016; Acquaotta et al., 2018).

In light of these observations, we outline that the geo-hydrological risk represents a major issue for the area (Brandolini et al., 2012), calling for urgent adaptation efforts. Moreover, given the complex geomorphological and environmental setting, Genoa's area is exposed to several other risks. In particular, the city's intense urbanization exacerbates the risk of heatwaves; the effects of water

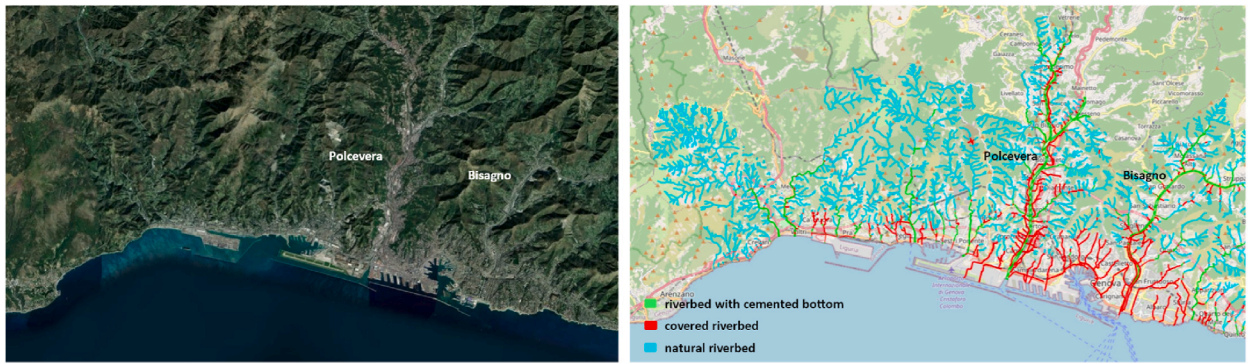


Fig. 3. Distribution of main and secondary rivers in the municipal area of Genoa. Source: Geoportal, Municipality of Genoa.

scarcity on the forests surrounding the area aggravate the risk of fires; and due to its position along the coastline, the city faces the increasing risk of coastal erosion and loss of marine ecosystem services (Bignami and Biagi, 2018; Spano et al., 2020).

In response to these multifaceted risk conditions, all the pertinent authorities have prepared a related set of land planning policies, as mentioned above. In particular, in terms of governing bodies, Genoa encompasses the Liguria Region and a series of local authorities. It is also the seat of the Metropolitan and Municipal authorities (Fig. 2 and Table 2).

Evidently, the multi-level policies that rule over the area of Genoa add an element of complexity to a territory already characterized by inherent fragilities.

3. Results

The following sections present the results emerging from the application of the UAST framework. Accordingly, these sections reflect the phases of the adaptation process as steps outlined by the UAST framework.

3.1. Preparing the ground for adaptation

This section focuses on the governance system put in place at different geographical levels to develop Genoa's adaptation process (Table 1, step 1).

The analysis found that the development of policy tools devoted to adaptation is not mandatory at sub-national levels in Italy. Nevertheless, in Liguria, a series of initiatives are being drafted, approved, and/or implemented through the involvement of multiple actors and the integration of strategies in different sectors and at various administrative levels, commonly known as horizontal and vertical mainstreaming, respectively (Table 1, step 1).

We deemed relevant investigating the implemented mainstreaming initiatives throughout the governance system, from the European to the municipal scale. Notably, in Italy, the policy framework is particularly complex, with initiatives related to climate adaptation scattered in a variety of documents, often not specific to this scope.

We found evidence in the policy documents that the adaptation process of the Genoa area was developed within the context shaped by the European and Italian policy frameworks, namely divided into official strategies/plans and collaborative networks/projects. Regarding the former, some of the main references are: i. the European Strategy on Adaptation to Climate Change, (European Commission, 2013; 2021); ii. the Italian Adaptation Strategy (Castellari et al., 2014), adopted in 2015; iii. the related operative plan (Ministry of Environment and Energy Security, 2022a), which remained a draft from 2017 to late 2023 and, thus, lacking legal relevance until recently; iv. the Italian National Integrated Plan for Energy and Climate, published in 2019 and currently under revision (Ministry of Enterprises and Made in Italy et al., 2019); and v. the Italian Ecological Transition Plan, approved in 2022 (Ministry of Environment and Energy Security, 2022b). The main goal of these documents is to provide vertical coordination and support, by means of guidelines and knowledge transfer through the administrative levels, identifying sectors at risk, analyzing the consequences of impacts, and finding appropriate solutions to reduce vulnerabilities and improve resilience (Table 1, sub-steps 1.1,

Table 2

Main characteristics of the relevant administrative entities for the study area: Liguria Region, Metropolitan city of Genoa, and Municipality of Genoa.

Administrative entity	Corresponding level in the European Nomenclature of territorial units for statistics (NUTS)	Population (inhabitants as of January 01, 2023)	Area (km ²)	Population density (inhab/km ²)
Liguria region	NUTS level 2	1502624	5416.15	277.43
Metropolitan city of Genoa	NUTS level 3	813626	1833.75	443.70
Municipality of Genoa	LAU (Local Administrative Units)	558745	240.29	2325.29

Source: Elaboration of the authors on data retrieved from Istat, n.a.a, n.a.b.

1.2). In terms of multilateral and multilevel collaborations, we observed the importance of European initiatives, such as ERDF (European Regional Development Fund) funds or the Interreg Programmes, and the Covenant of Mayors, as well as the Italian CREIAMOPA project (Ministry of the Environment and the Protection of the Territory and the Sea, 2018). All these activities provided some fundamental prompts to the local adaptation processes, supporting the transfer of knowledge and resources among administrative levels (Table 1, sub-steps 1.3, 1.4).

When investigating the sub-national scales, we found that, in 2021, the Liguria Region approved the Regional Strategy for Sustainable Development (RSSD) (Liguria Region, 2021), which also mentions the goal of strengthening resilience and sustainability through adopting immediate climate-related actions. Following the RSSD and the national guidelines (Sogesid – CREIAMO PA Per un cambiamento sostenibile, 2020), the Liguria Region shaped a Regional Strategy for Adaptation to Climate Change (RSACC), approved in early 2023 (Liguria Region, 2023). It recommends horizontal coordination in developing climate adaptation objectives and measures, engaging the regional departments and their sectoral plans, such as the Hydro-Geological, Regional Landscape, Flood Risk Management, and Infrastructure, Mobility and Transport Integrated Regional plans (Table 1, sub-step 1.3). Furthermore, aligned with the national level, this strategy aims to support the sub-regional levels in analyzing sectoral and territorial vulnerabilities and shaping the most suitable responses (Table 1, sub-step 1.1).

Nevertheless, as confirmed by our informed co-author, the delayed development and approval of the RSACC limited the role of the Region as a guide for the local adaptation process. Rather, we noticed that the Metropolitan City and several municipalities within it (Genoa included) defined their own priorities without systematic coordination with the regional authority, initiating the adaptation process independently and relying mostly on involvement in European projects and transnational networks (Table 1, sub-step 1.1). Indeed, the mentioned multi-level collaborations shaped some important policy tools at the metropolitan scale, namely the Metropolitan Strategic Plan and Green Infrastructure for Adaptation to Climate Change Guidelines (hereafter, Green Infrastructure Guidelines) (Table 1, sub-step 1.1). In particular, the Metropolitan Strategic Plan fosters local adaptation and resilience toward geo-hydrological risk, while the Green Infrastructure Guidelines provide nature-based solutions for the management of urban rainwater.

Finally, at the municipal level, the research revealed that some especially important acts are the Municipal Civil Protection Plan, which is legally binding for Italian municipalities and was revised by Genoa in 2019, and the Genoa Lighthouse 2050, a broad planning tool with a long-term vision, which intended to address three major global challenges (i.e. the climate, demographic and technological issues). Furthermore, regarding adaptation efforts, we evidence the importance of the municipality of Genoa's adherence since 2009 to the Covenant of Mayors, which supports the development of a Sustainable Energy and Climate Action Plan (SECAP) (Table 1, sub-step 1.1). Our informed co-author verified that, accordingly, the Genoa municipality tailored and optimized the internal administrative structure, financed the process, and promoted the engagement of institutional stakeholders, through various dedicated initiatives, such as interviews, workshops, planning sessions, and public events, intended to collect their privileged information (Table 1, sub-steps 1.2, 1.3, 1.4, 1.6, 1.8). Regional and local research centers, including the Ligurian Environmental Protection Agency (ARPAL), International Center for Environmental Monitoring (CIMA) Foundation, and the University of Genoa, as well as industry representatives, were involved. The municipality also fostered the processes established during previous initiatives, such as those related to the Sustainable Urban Mobility Plan, the Urban Center office, and the Genoa Lighthouse 2050. These endeavors led to the involvement of new stakeholder groups, such as professional associations, labor unions, and the association of condominium administrators, e.g. by means of a dedicated questionnaire. Along with the municipal initiatives, we realized that the local level benefited from engagement activities promoted at the regional level. In particular, the Liguria Region activated and funded (Table 1, sub-step 1.5) the 14 regional Environmental and Sustainability Education Centers (ESECs), many of which were focused on Genoa. The ESECs managed multiple engagement activities, including video and photo reports, information campaigns, thematic escape rooms, excursions, and events, in partnership with local administrations and associations, with the goal of involving, informing, and raising awareness of locales (Table 1, sub-step 1.7).

All of these stakeholders recognized heavy rains, floods, landslides, forest fires, and heatwaves as the major hazards for the Genoa area and showed their comprehensive understanding of the urgency of taking action. Stakeholders suggested maintenance, restoration, and arrangement interventions as priority adaptation measures to address the identified vulnerabilities. In addition, they proposed cross-cutting actions, such as improving communication and environmental education and raising awareness (Table 1, sub-step 1.7). The need to update the environmental legislation to include climate adaptation also emerged, with a further demand for coherent policies and monitoring systems. Stakeholders also emphasized the need to create a common agenda with the Public Administration aimed at streamlining access to funds and incentives.

3.2. Assessing climate change risks and vulnerabilities

In this section, we focus on the assessments of the past and future climate trends, and Genoa's climate risks and vulnerabilities, which allowed identification of the most relevant adaptation objectives for the area (Table 1, step 2).

We found evidence that several studies performed at the national (Esposito et al., 2015; ISPRA, 2015; Servizio Meteorologico dell'Aeronautica, 2008; Istat, 2022), regional (Arpal, 2013; Cima Foundation, 2021), and municipal levels (Municipality of Genoa, 2020) explored the past and current trends and elaborated climate scenarios and projections in terms of precipitation, temperature, and occurrence of extreme events (Table 1, sub-steps 2.1, 2.2, 2.5). Moreover, the collaboration between the Liguria Region, CIMA Foundation, and ARPAL allowed the establishment of an observation system at the regional level. The analyses showed that the past trends in temperature and precipitation are expected to be confirmed in the future. In particular, the Genoa area will reasonably face an increase in mean temperatures, as well as in the intensity and occurrence of extreme rainfall events. Consequently, as highlighted by the SECAP, heatwaves and, above all, geo-hydrological hazards were recognized as major threats to the area, and will seemingly

worsen in the future (Pirlone et al., 2020).

We observed that the Liguria Region, in close collaboration with regional research centers (University of Genoa, Liguria Ricerche, and CIMA Foundation), undertook a sound climate risk and vulnerability analysis (Table 1, sub-steps 2.3, 2.4, 2.5) considering local socioeconomic and environmental factors, which were then explored in depth by the SECAP. Such analysis converged in the design of specific impact chains (IPCC et al., 2014), which later helped define the adaptation objectives and measures (Table 1, sub-step 2.6). These are conceptual models that show cause-effect chains leading to specific climate risks in a certain context, thus enabling policymakers to understand the impacts of climate change on a studied area (Zebisch et al., 2022) and providing information especially valuable for adaptation strategies and plans. Specifically, the RSACC developed an impact chain for each of the 12 socio-economic sectors identified as most vulnerable against the emerging major hazards: Agriculture and breeding; Forests; Fishery, aquaculture, and marine ecosystems; Water resources; Health; Tourism; Urban systems; Hydrological risk and civil protection; Energy; Infrastructures and transportation; Coasts; and Land ecosystems (Table 1, sub-step 2.4).

Due to space constraints, only one sector is presented in this study. Table 3 summarizes the impact chain related to “Urban systems”, one of Genoa’s most susceptible socio-economic sectors. Notably, the risk scenario concerns flooding, a major issue for Genoa. The impact chain first considered the expected climatic drivers, which are increased rainfall intensity and occurrence of extreme events. Such alterations are projected to exacerbate the impact of floods. These events are likely to damage exposed assets, including buildings and transport infrastructure. In particular, vulnerabilities were described in terms of the relevant characteristics of the built environment, such as the presence of buildings or infrastructure in flood-prone areas. Response capacities were related to measures like infrastructural maintenance plans. The last phases of the impact chain deduced potential risks and relevant adaptation objectives for the area. The major identified risks referred to the expected increasing damages to the urban built environment. Accordingly, adaptation objectives especially supported the strengthening of prevention, monitoring, and early-warning systems, along with the engagement of local communities.

3.3. Identifying adaptation options

This section explores the activities that prepare the selection and implementation of the adaptation options (Table 1, step 3). Here, the main focus is on the collection and systematization of the available best practices in terms of urban adaptation. We noticed that, although such preparatory activities were performed for the municipal, metropolitan, and regional processes, a rather limited discussion of such steps in the analyzed documents prevents the in-depth examination. In addition, it is noteworthy to consider the inherently different visions of the documents, which translate into different approaches toward the adaptation options. Indeed, the SECAP intends to directly act on the area, introducing operating solutions to local issues. Conversely, the RSACC is more focused on defining objectives and targets, thus demanding the related enactment to the departments of the Regional Authority. Despite these shortcomings, information was gathered by one of the authors, who was directly involved in developing the RSACC. In particular, in terms of preliminary exploration of the available adaptation options (Table 1, sub-step 3.1), an initial catalog was progressively built and refined during the meetings between CIMA Foundation and the departments of the Regional Authority. Significantly, the impact chains clarified the conditions and priorities of the area, thus informing the following planning phase and bridging two different steps

Table 3

Impact chain related to the socio-economic sector “Urban systems”. Source: Authors’ elaboration based on data of CIMA and Liguria Ricerche.

Impact chain	
<i>Climate driver</i>	Increase in rainfall intensity Increase in extreme rainfall events
<i>Impact</i>	Floods
<i>Exposure</i>	Buildings Transport infrastructure
<i>Vulnerabilities</i>	Percentage of buildings or road infrastructure close to the coast and/or in areas at geo-hydrological risk Sealing of manholes Historical buildings
<i>Response capacities</i>	Rainwater drainage capacity Infrastructure and building maintenance plan Number of Ligurian municipalities with Sustainable Energy and Climate Action Plan (SECAP) and with Risk and Vulnerability Assessment Civil protection plan and flood-proofing systems Urban green areas and application of SUDS (Sustainable Drainage System) models Re-watering and re-naturalization interventions Construction of lamination/containment basins Adoption of green building techniques and passive protection systems for building envelopes Consistency with the Flood Risk Management Plan Monitoring of climatic variables at the urban level Development of early-warning systems along with continuous improvement of forecasting models, with active participation of stakeholders Experimental adaptation interventions on a building level
<i>Risk</i>	Increased damage to buildings and infrastructure in urban areas
<i>Adaptation objectives</i>	Promote plans and activities for risk prevention and monitoring enhancement Promote experimental adaptation interventions in peri-urban areas, suburbs, and historical centers, with particular reference to public spaces Increase knowledge, education and training on climate risks and possible adaptation measures at the urban level

Table 4

Adaptation actions included in the SECAP and Genoa Lighthouse 2050, with some of the main related information; actions with a star are in common.

Action	Climate driver	Sector	Borrowed from previous initiatives	Duration (expected)	Approach	Funds (approximation)	Enacting authority
CLOUDBURST*	Heavy rains	Water Transport	No	duration: n. a. end: 2025	gray (engineered) green (nature-based)	TBD, municipality's own funds or other financing (such as structural and European funds), 0.1M €	Genoa Municipality
Enhancement of peri/urban green areas	Multi-driver	Agriculture	Yes	duration: n. a. end: 2025	soft (non-structural) green (nature-based)	municipal, regional and European funds, 0.12M €	Genoa Municipality
FORCE project	Forest fires Heavy rains	Agriculture	Yes	duration: 5 years end: 2021	soft (non-structural)	European funds (Horizon2020 programme), 0.22M €	Genoa Municipality
UnaLAB project	Heavy rains Heatwaves	Environment and biodiversity	Yes	duration: 5 years end: 2022	gray (engineered) green (nature-based)	European funds (Horizon2020 programme), 14M €	Genoa Municipality
RIGENERAZione*	Heavy rains Heatwaves	Environment and biodiversity Land planning	No	duration: 2.5 years end: 2025	gray (engineered) green (nature-based)	TBD, municipality's own funds or other financing (such as structural and European funds), 1M €	Genoa Municipality
Redevelopment of the Fiera-Kennedy area	Heavy rains Heatwaves	Land planning	Yes	duration: 5 years end: 2024	gray (engineered) green (nature-based)	national funds (Ministry of Enterprises and Made in Italy and Ministry of Culture), 35M €	Genoa Municipality
Polcevera Park and Cerchio Rosso	Heavy rains Heatwaves	Land planning	No	duration: 11 years end: 2030	gray (engineered) green (nature-based)	structural funds (METRO National Operational Program) and others, first phase 2.5M €	Genoa Municipality
Digitalization of geodata on adaptation and mitigation	Multi-driver	Land planning	No	duration: 3 years end: 2022	soft (non-structural)	n.a.	Genoa Municipality
Emergency management information system	Multi-driver	Civil protection and emergencies	Yes	duration: 3 years end: 2019	soft (non-structural)	structural funds (METRO National Operational Program), 0.07M €	Genoa Municipality
Participatory civil protection planning	Multi-driver	Civil protection and emergencies	No	duration: TBD end: TBD	soft (non-structural)	TBD, municipality's own funds or other financing (such as structural and European/national funds), 0.15M € expected	Genoa Municipality
Teaching support material on civil protection	Multi-driver	Civil protection and emergencies	Yes	duration: 2 years end: 2022	soft (non-structural)	n.a.	Genoa Municipality
CLIMACTIONS project	Heatwaves	Health	Yes	duration: 2 years end: 2022	soft (non-structural) green (nature-based)	national funds (Ministry of Health), 0.45M € total	Genoa Municipality
CLEAN AIR*	Heatwaves	Health	No	duration: 2 years end: 2025	gray (engineered) soft (non-structural)	TBD, municipality's own funds or other financing (such as structural and European/national funds), 0.2M € expected	Genoa Municipality
UNESCO SENTINEL*	Heavy rains	Buildings Tourism	No	duration: 1.5 years end: 2025	soft (non-structural) gray (engineered)	TBD, municipality's own funds or other financing (such as structural and European/national funds), 0.25M €	Genoa Municipality
RIV.eco	Multi-driver	Policy	No	duration: 1–3 years end: n.a.	soft (non-structural)	n.a.	Genoa Municipality

of the adaptation process.

Our informed co-author also observed the relevant role of the workshops that gathered the Ministry for the Environment and other Regional Authorities (e.g. the CREIAMOPA initiative) to aid the selection of measures to be implemented (Table 1, sub-step 3.2). Indeed, our co-author witnessed how the shared results and remarks influenced the ongoing activities in the Liguria Region and steered the selection of adaptation options toward those already proven to be effective.

3.4. Assessing and selecting adaptation options

This section explores the processes that narrowed down the available adaptation options, and eventually selected and prioritized the most relevant ones (Table 1, step 4). Also, in this case, we could not clearly recognize the recommended UAST sub-steps in the studied documents. However, based on the insights gathered by the informed co-author, it emerged that some evaluations were performed with a non-structured approach, especially in terms of formal assessment of the adaptation measures (Table 1, sub-step 4.1).

An important component of this phase is the cost-benefit analysis (Table 1, sub-step 4.2), increasingly recognized as a pivotal tool to support local authorities in evaluating and selecting adaptation options. Nevertheless, due to the complexity of some variables, a formal cost-benefit analysis may prove tricky for local authorities, while economic assessments are commonly performed. In the case of Genoa, we could not identify a formal cost-benefit analysis (e.g. in the Genoa Lighthouse 2050), though the SECAP assessed some of the selected adaptation measures in terms of costs, related to both investments, and functioning and maintenance.

This preparatory process for the local adaptation has a closing phase in the selection of a first set of measures for implementation (Table 1, sub-step 4.3). We observed that in the cases of the Genoa Lighthouse 2050 and SECAP this phase did not follow a structured process; rather, it referred to the previous climate and vulnerability analyses, and the consultation with the stakeholders. Nevertheless, the SECAP eventually prioritized 14 adaptation options, while the Genoa Lighthouse 2050 selected 12 actions, including only 5 related to adaptation. Concerning the regional efforts, we found that the RSACC provides only some indications on the implementation tools that could help achieve the proposed objectives, mainly related to enacted laws and plans at different levels.

3.5. Implementing adaptation

This section explores the core of the adaptation process: the design and implementation of an action plan (Table 1, step 5).

As mentioned, several governing bodies oversee the territory of Genoa, issuing different guidelines and policies, thus complicating the governance and action on local adaptation. Notably, the municipality issued some action plans (Table 1, sub-step 5.1). In particular, the SECAP is by definition an action plan, while the Genoa Lighthouse 2050 comprises both strategic and action plans (Table 1, sub-step 5.1). However, we could not verify whether they considered other urban adaptation plans as examples (Table 1, sub-step 5.2).

It was interesting to observe that some actions included both in the SECAP and Genoa Lighthouse 2050 are recalled in the Civil Protection Plan, providing an example of horizontal mainstreaming (Table 1, sub-step 5.3). Conversely, we noticed that the collaboration between the regional and municipal authorities appears limited and confined to the planning phases (regarding only 1 action, that is the CLIMATEACTIONS project, see Table 4), thus limiting the effectiveness of vertical mainstreaming (Table 1, sub-step 5.3). Finally, we observed that the SECAP adopted a number of adaptation actions that also have positive impacts in terms of mitigation (Table 1, sub-step 5.4). For instance, some adaptation measures are intended to manage and enhance urban green areas by means of new walking and cycling lanes, that, in turn, would also contribute to mitigating transport-related emissions (e.g. actions related to the Enhancement of peri/urban green areas or to the Polcevera Park and Cerchio Rosso, see Table 4).

Due to the relevance for local adaptation, we more closely analyzed the 14 actions included in the SECAP and the 5 adaptation-related actions of the Genoa Lighthouse 2050. Since the two plans share 4 actions, a total of 15 actions were considered (Table 4 and Appendix B Table B.1). These measures cover all the climate drivers identified for the area, and reflect its specific spatial organization and vulnerabilities. The concentration of the population along the coasts and main watercourses, such as the Bisagno and Polcevera, required targeted measures for hydrogeological risk management, with particular attention to riverbeds and flood risk. Therefore, adaptation actions had to take into account the local complex orography, thus including stormwater management and reforestation of hillside areas, which are prone to landslides and wildfires. Furthermore, the fragmentation of the urban fabric has encouraged solutions such as the creation of peri-urban green spaces and ecological corridors, that aim at reducing the impacts of heatwaves and improving the overall resilience of the area. Against this background, it is relevant to stress how particular attention is placed on tackling the consequences of heavy rains, following the evidence that geo-hydrological risk is a widely recognized priority. The land planning and civil protection sectors are most frequently mentioned, thus suggesting a specific focus on the inherent fragilities of the territory, especially in the case of extreme events.

Moving from the rationale to the characteristics related to enactment, our analysis showed that a relevant share of the selected actions (7 out of 15) were borrowed from other projects and initiatives, which suggests the limited capacity of these plans to foster adaptation through original activities. In addition, the realization of most of the selected actions is expected in the short-term, as it exceeds 5 years in few cases, suggesting a narrow vision over time that hinders the effectiveness of these plans. Considering the type of actions indicated, despite being rather diverse, 10 out of 15 either exclusively (6) or partly (4) adopt a soft approach, focusing on the preparatory activities related to managing, organizing, raising awareness, and collecting data, thus having limited transformative potential. The remaining 5 actions propose a mixed gray/green approach, involving respectively engineered and nature-based solutions, and could significantly impact the territory; however, they mostly assume a pilot project perspective (e.g. UnaLAB project) or concern a narrow area (e.g. the redevelopment of the Fiera-Kennedy area covers 7.2 ha), thus again presenting a limited transformative

effect. Our analysis revealed a further limitation that refers to funding; when the documents were published, a large share of the actions (8 out of 15) were still to be defined, either in terms of source or quantity, or both. Finally, we stress that, regardless of the funding source, the municipal authority performs the operative enactment for all 15 actions, thus highlighting the pivotal role of this governing level in the area's adaptation.

3.6. Monitoring and evaluating adaptation

The last step in the process concerns monitoring and evaluating the enacted adaptation efforts (Table 1, step 6).

In the case of Genoa, the relevance of these activities emerged through the governing levels, as all the considered adaptation tools mention the willingness to follow the implementation of the envisaged actions (Table 1, sub-step 6.1). In particular, the RSACC and SECAP hint at adopting a framework similar to a policy cycle, where the monitoring and evaluation activities not only inform the efficacy of the efforts, but also suggest possible improvements to the overall strategy/plan (Table 1, sub-step 6.1).

Importantly, the indicators are consistently identified as the most appropriate tool (Table 1, sub-step 6.2). The RSACC is rather transparent regarding the selection process, and mentions the benefit of referring to consolidated metrics, such as those published by the Italian National Institute of Statistics on the SDGs (Table 1, sub-steps 6.2 and 6.3). Notably, the RSACC demands the quantification of the related monitoring indicators to the regional departments. Conversely, the Genoa Lighthouse 2050 appears efficient in grouping the selected indicators in thematic domains, although we did not find particularly clear which metrics were chosen (Table 1, sub-step 6.2). However, we considered it especially relevant analyzing the approach of the SECAP as the implementation of the adaptation actions appears to rely mainly on the municipality. In this case, we understood that the selection of the monitoring indicators was an integral part of the process concerning the definition of the adaptation actions (Table 1, sub-step 6.2), although the guiding criteria were not particularly clear (Table 1, sub-step 6.3). In addition, the SECAP envisages a further monitoring and evaluation approach, consisting of participatory processes (Table 1, sub-step 6.1).

Nevertheless, as a limited share of actions is currently enacted, here it is possible to explore only the indicator-based approach. Interestingly, the indicators selected in the SECAP relate to two main categories: process-oriented or outcome-oriented. In particular, the former ones measure implementation progress (e.g. changes in protected area surfaces, changes in availability of water resources), while the latter evaluate the effectiveness in terms of increasing the adaptive capacity and reducing vulnerability (e.g. number of hospitalized people due to heatwaves, number of invasive species). Unfortunately, although the monitoring report of the SECAP was completed in late 2023, it has not yet been published; hence, we still could not verify how the monitoring and evaluation process was developed (Table 1, sub-step 6.4).

4. Discussion

In this study, we assessed the contribution of each governing level to local adaptation, with the aim of identifying which level made the main adaptation effort in the area of Genoa. To this end, we referred to the UAST framework to perform a plan content analysis of the climate policies developed at the local levels: regional, metropolitan, and municipal. Notably, our informed co-author aided the collection of relevant, integrative insights on the analyzed documents. In the following sections, we gather the main findings of this study, along with the main emerging issues and some policy recommendations to overcome them.

4.1. Main findings: the duality of local adaptation

Our analysis on the adaptation process in the Genoa area revealed a duality in the adopted approach.

Concerning preparatory activities and preliminary analyses of the adaptation process (steps 1, 2 and 3 of the UAST), we found a coordinated and integrated approach, appreciable in terms of production and sharing of knowledge among local institutions, regarding area-specific analyses on the local climate impacts, risks, and vulnerabilities. We noticed that regional institutions performed their designated technical role by providing detailed studies that availed the other governing bodies, which, in turn, further tailored them to the related area and included them in the enacted documents. Moreover, the multiple activities to engage local stakeholders emerged as a further element of integration between governing levels. Indeed, our investigation verified an overall agreement among technical analyses and stakeholder perceptions on the area's climate-related issues and the urgency of developing adaptation policies. Accordingly, we observed that the efforts of coordination and shared policy development led to the selection of actions that actually respond to the commonly advocated need to reduce local risks. To sum up, we outline that a sound synergy in producing and sharing knowledge and expertise among the different governing levels improved the effectiveness of these first steps in the adaptation process. Interestingly, a sound and permeable science-policy interface has already been advocated in the literature, though no consistent evidences were found (Clar and Steurer, 2019); the case of Genoa may be among the few examples of a fruitful exchange of knowledge and information between local scientific institutions and authorities, as well as within local authorities (Fünfgeld et al., 2023).

However, we evidence that such an integrated approach was not thoroughly enhanced in the UAST's final steps (4, 5, and 6), which comprised the selection, implementation, and monitoring of the envisaged actions (e.g. when transforming the previous studies and plans into working actions). In fact, the analyzed documents show that the realization of the envisaged measures is predominantly fostered by the local municipal authority. We highlight this significant shortcoming considering that Genoa frequently selected measures related to land planning and regulation that would benefit from extensive coordination with other authorities. Notably, higher-level (regional, national, European) authorities are mainly focused on their role of outlining guidelines, identifying appropriate objectives, and promoting awareness-raising initiatives. It follows that lower-level authorities, and especially municipalities, are on the

frontline of adaptation in the effort to advance such a process, even anticipating the acts of other authorities, confirming a trend already emerging in Europe (see e.g. Reckien et al., 2018). In the case of Genoa, the municipality approved its SECAP two years before the regional authority issued its RSACC and three years before the national authority approved the Adaptation Plan. In fact, this subdivision of governing roles is attributed to the common European, national, and sub-national approach, which applies the principle of subsidiarity (Carozza, 2003). This principle recognizes the need to share responsibilities and roles among administrative levels, assigning functions to the authority at the lowest possible level that does not compromise the action's effectiveness (Carozza, 2003). Though this might be advantageous in terms of proximity to the issues to be solved, we recognize that other significant problems might emerge. For instance, while implementing adaptation measures is already challenging for larger municipalities such as Genoa, these challenges can be unmanageable for smaller municipalities. This is a relevant matter for Italy, where 70 % of the 7904 municipalities have less than 5000 inhabitants (Istat, n.a.a): these various small municipalities (as defined by National Law n. 158/2017) often lack human and economic resources, and are, thus, unable to pursue an appropriate adaptation path. Notably, this barrier has been widely reported (Fünfgeld et al., 2023), also in the case of municipalities in southern European countries (such as Italy) (Aguilar et al., 2018). In addition, the case of Genoa suggests that municipalities might rely on a pilot project-oriented approach. While interesting in terms of urban experimentation and innovation (Castan Broto, 2017), this approach may not necessarily translate into an overall, long-term strategic transformation of the territory (Fünfgeld et al., 2023), especially if the number of implemented adaptation measures is low and they encompass a narrow area of influence. Interestingly, it has been already pointed out that a strong mandate and support from regional and provincial authorities can significantly enhance the capacities of municipalities (Baynham and Stevens, 2013; Lyles et al., 2017; Pietrapertosa et al., 2021). To sum up, we highlight that this complex condition of limited integration when realizing selected measures and extensive reliance on local resources can severely undermine adaptation efforts. In particular, it can likely hinder the overall transformative potential of the enacted documents, thus becoming a missed opportunity to foster an effective local adaptation path. Indeed, we remark that municipalities have already been recognized as potential privileged partners for higher-level authorities in local climate action (Kona et al., 2018)—but only if they are in the conditions to effectively contribute.

4.2. Constraining factors

In light of the above, we identified six constraining factors of adaptation. Five factors are overarching, but can jeopardize adaptation efforts at the local level. First, in Italy, adaptation strategies and plans are not mandatory at the sub-national levels, easily leading to a scarcity of commitment among the various governing levels. Second, even when committed, local governments usually refer to a timeframe limited by their political mandate, usually irreconcilable with the long-term perspective of adaptation processes. Third, the seven year delay in approving the national adaptation plan implies that there were no operative requirements or guidelines available to the local authorities. Fourth, the complex and multilevel policy framework hampers the integration and coordination of adaptation measures among and across governing levels. Fifth, connected to the previous, the variety of policy tools that authorities can avail makes their coordination and systematization challenging already at a specific level of government, further curbing local adaptation.

The sixth factor is more specific compared to the others and concerns the lack of control, steering, and systematization among the selected and implemented adaptation options. The scope of this activity would be: i. to extend the pilot-project approach to a larger-scale transformative perspective intended to cover the overall pertinent territory; ii. to create agreement and synergy among the actions affecting neighboring areas; and iii. to verify if the number and potential of the selected actions are sufficient, or if there is a residual risk that needs to be addressed in the following cycle of adaptation. This sixth factor can lead to the inability of the adaptation actions to reshape the territories, aggravating the local vulnerability to climate impacts. Furthermore, we evidence the importance of extending the mentioned comprehensive activity to the monitoring and evaluation phases. Indeed, evaluating the impacts and ensuring that these evaluations inform the revision of the overall plans would guarantee that the policy cycle progresses in a coordinated and integrated way throughout the overall area, as also the UAST framework remarks.

Given the importance of understanding and addressing the sixth factor for the adaptation cycle, we examined more in depth its policy background. To begin with, the European strategy fulfills its function of providing general guidance, particularly suggesting the application of policy coherence principles. The Italian national strategy and plan propose dedicated technical bodies to verify the agreement and adequacy of adaptation actions. Additionally, they indicate the regional level to provide technical support to local institutions, and mandatory or voluntary forms of local coordination to integrate governing levels. Notably, the role of local coordinator is also recognized by the Covenant of Mayors, further legitimizing that endeavor, as municipalities often refer to this same initiative to build their adaptation processes. However, the agenda of the adaptation plan will remain on hold as long as the national government will not issue an implementation decree. Though this decree is expected in the near future, it becomes a further delay in the actual enactment.

4.3. Policy recommendations

In view of the emerged constraining factors, we propose some policy recommendations intended to foster effective adaptation. The first, second, and third factors concern some normative limits that we recommend addressing: i. by strengthening the involvement of local authorities, as far as requiring a mandatory strategic and/or planning effort; ii. by avoiding delays in practical guidance, that severely undermine the adaptation capacity of the sub-national governing levels and force antecedent local strategies/plans to be later adjusted, thus adding complexity to the adaptation process. The fourth and fifth factors relate to the normative framework, too, though more structural in nature. Indeed, they refer to how regulations are designed, enacted and enforced, often interlacing and overlapping

each other. Consequently, this condition can hardly be transformed, as it inherently entails a sound commitment in the long term, that challenges the underlying assumptions and eventually the overall normative framework.

Finally, the case study of Genoa shows that local authorities (i.e. the regional and the municipal ones) often overlook the mentioned lack of operative guidance, here identified as the sixth factor. We evidence that the national strategy and plan assign the role of control, steering, and systematization among the adaptation actions to the regional authorities. Hence, we strongly suggest that the regional institutions actively assume the role of providing local coordination, strengthening their synergy with the Covenant of Mayors initiative. In addition, we recommend a thorough commitment of municipal authorities in implementing sound climate action. Indeed, our research evidenced the common trend of relying on pilot-project approaches that lack a comprehensive vision for the area. Consequently, it is fundamental to devise a robust plan for climate action that transcends the inherent political instability within municipal authorities and strengthens local climate resilience in the long term. In this perspective, working in collaboration with neighboring municipalities, also preparing and designing common action plans, also envisioned by the Covenant of Mayors, could significantly improve local coordination and agreement among adaptation measures, as well as optimize available resources.

We emphasize that, in Italy, given the current structure of the overall adaptation process, integration is crucially missing in translating the proposed planning tools and objectives into working measures that effectively and comprehensively impact the whole territory—a condition that can compromise the successful adaptation of an area.

4.4. Limitations of this study

Although our study provided some relevant understandings on local adaptation processes, adopting an innovative approach of analysis, some limitations can be recognized and possibly overcome in future studies. For instance, as the analyzed case study concerns only the Genoa area, it might be relevant to adopt a vertical approach to explore how other territories are dealing with the adaptation process, in order to draw insights on different national and sub-national contexts, especially in European countries. In addition, the effort to tackle climate change encompasses both adaptation and mitigation measures, hence it might be interesting to investigate how this joint process is evolving. Eventually, the proposed analysis is based on documents that are currently being issued and/or revised, hence it might be relevant to check the local policy development in the near future.

5. Conclusion

The case of Genoa provides key insights on the process of local adaptation to climate change, by exploring how involved authorities might share the burden of such a challenge. This research revealed that the actual implementation of a sound integration among different institutional levels can induce significant outcomes. For instance, sharing knowledge among stakeholders leads to assessments that are tailored to the local characteristics and inform policies focused on local needs; at the same time, it allows the local population to participate in the policy process, thus furthering their approval and engagement.

Nevertheless, our study evidenced that when an integrated approach among local authorities becomes flawed, the responsibility of implementing adaptation is unevenly distributed among concerned actors. Moreover, municipalities might end up playing a major role. Such a consequence represents a serious issue in the Italian context, where municipalities are often not equipped with adequate human and economic resources.

We identified six main factors leading to this condition: i. Lack of mandatory adaptation commitments at the sub-national levels; ii. Mismatched timeframes of governments mandate and adaptation processes; iii. Delayed approval of an adaptation plan at the national level; iv. Complexity of the multilevel policy framework; and v. Complex variety of available policy tools; vi. Lack of control, steering, and systematization of adaptation measures. This situation can lead to solutions that have only a limited effect on local vulnerabilities, hindering the overall adaptation process. Consequently, we stress the urgency of addressing these constraining factors, especially in terms of strengthening the strategic/planning effort of local authorities, providing timely practical guidance, and compelling intermediate levels of government to undertake a role of control and monitoring over local adaptation processes. The proposed policy recommendations are meant to contribute to fostering effective local climate change adaptation. Their scope concerns not only the area of Genoa, but also other European countries, where the mandate of municipalities to play a central role in this process is strong, as the relevance recognized to the Covenant of Mayors initiative demonstrates, yet the available human and economic resources are not always up to the challenge. More in general, wherever a complex, multilevel governance is in place to tackle climate adaptation, we stress the importance of a sound effort of coordination and shared planning, both among and within governing levels, to establish a robust and stable vision for the adaptation of the area in the long term.

CRediT authorship contribution statement

Alessandra Colocci: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Antonella Pietta:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Francesca Caviglia:** Writing – original draft, Visualization, Investigation, Data curation. **Marco Bagliani:** Writing – original draft, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to

influence the work reported in this paper.

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Appendix A. Selected strategies and plans analyzed for the case study of Genoa

Table A.1

Links to the most relevant analyzed documents, per considered governing level (last accessed: December 11, 2023).

Governing level	Document	Link
Regional	Regional Strategy for Adaptation to Climate Change (RSACC)	https://www.regione.liguria.it/homepage-ambiente/cosa-cerchi/sviluppo-sostenibile/strategia-adattamento-cambiamenti-climatici.html
Metropolitan	Metropolitan Strategic Plan	https://pianostrategico.cittametropolitana.genova.it/content/piano-strategico-metropolitano
Municipal	Sustainable Energy and Climate Action Plan Genoa Lighthouse 2050(strategic and action plans)	https://smart.comune.genova.it/content/secap https://www.genovameravigliosa.com/en/download

Table A.2

Most relevant policymaking processes that one of the authors participated in and the related targeted stakeholders.

Policymaking event	Targeted stakeholders
3 workshops (07/06/21, 08/07/21 e 29/09/21)	Regional managers and officials, Environment and Civil Protection Department acting as Regional Environmental Management Authority CIMA Foundation researchers University of Genoa researchers
Informal meeting during the Regional Forum for Sustainable Development (October 22, 2022)	Metropolitan City of Genoa administrators and officials Ligurian Environmental Protection Agency Municipality of Genoa administrators and counselors Industry representatives and private companies, third sector entities, wider public and local citizenship
Public event of the European project Evoforest (November 18, 2022)	Municipality of Genoa administrators and counselors
Winter School "Public management of adaptation to climate change: the role of the Regions" (13–15/12/2021)	CRElAMOPA experts Regional managers and officials
Technical support for the finalization of the RSACC (20–21/11/2022)	CRElAMOPA experts

Appendix B. Analyzed adaptation actions for the municipality of Genoa

Table B.1

Analyzed actions related to adaptation and included in the SECAP and Genoa Lighthouse 2050.

Adaptation action	Pertinent action plan	Description
CLOUDBURST	SECAP and Genoa Lighthouse 2050	The action aims at reducing the damage caused by extreme rainfall by optimizing and improving the infrastructure devoted to the collection and run-off of meteoric water. A pilot case is foreseen in 10 flood-prone areas.
Enhancement of peri/urban green areas	SECAP	The action consists of a set of activities intended to enhance the forestry component of the municipal area, developing management that favors broader access and the reduction of forest-related risks.
FORCE project	SECAP	The action encompasses two activities: a study to evaluate the potential amount of mowing and pruning within the urban area of Genoa, and a project aimed at creating a short wood-energy supply chain based on the use of local biomass in the Genoa area (Val Polcevera). The action affects the local forestry management, with the aim of reducing the vulnerability of the territory towards the risks of forest fires and extreme rainfall.

(continued on next page)

Table B.1 (continued)

Adaptation action	Pertinent action plan	Description
UnaLAB project	SECAP	The project aims at renovating the Gavoglio area in the Lagaccio district through the demolition of the former military barracks and development of a public, inclusive, and sustainable urban park using nature-based solutions.
RiGENERAZione	SECAP and Genoa Lighthouse 2050	The project envisages urban regeneration interventions in at least 10 city sites (gardens, urban squares, open spaces, etc.) with the aim of improving resilience to climate change. The sites and interventions will be established in a participatory way through public–private partnership agreements.
Redevelopment of the Fiera-Kennedy area	SECAP	The action focuses on local redevelopment interventions. In particular, it includes the rehabilitation of the sea front and the creation of an urban park in order to improve the accessibility, integrate the square within the urban fabric, enhance the perception of the area, and introduce greenery and shading systems.
Polcevera Park and the Red Circle	SECAP	The project focuses on the transformation of the Val Polcevera area, under the former Morandi Bridge. It foresees a new Conservation Center for Mediterranean Biodiversity, a pedestrian-cycle path (named the Red Circle) embracing both banks of the River Polcevera, and a 120-m-high wind tower that will make the area carbon neutral.
Digitalization of geodata on adaptation and mitigation	SECAP	The action aims to upgrade the municipal geoportal (“ <i>Corner dati per l’adattamento e la mitigazione del Cambiamento Climatico</i> ”, in Italian) by developing a dedicated dashboard that reports data on climate change and displays the monitoring of planned and ongoing adaptation actions.
Emergency management information system	SECAP	The initiative aims to develop a new information system for emergency management, providing a digital platform on which municipal Civil Protection interventions are managed in a centralized way.
Participatory civil protection planning	SECAP	The project consists of the Municipal Civil Protection Plan review and update through a participatory process to improve emergency management and increase public awareness.
Teaching support material on civil protection	SECAP	The action involves creating a kit of teaching units for teachers (“ <i>Pillole di Protezione Civile</i> ”, in Italian) with the aim of training and informing students on local risks and correct behaviors in the event of disasters. The material concerns: Flood, Civil Protection System, Civil Protection Culture, Risk Perception and Resilience, and Sustainable Development.
CLIMACTIONS project	SECAP and Genoa Lighthouse 2050	The project promotes adaptation and mitigation measures for the effects of heat waves in urban areas, aimed at health benefits and greater livability in the urban context. To this end, the creation of innovative tools is proposed to support the decision-making process in large urban areas, using GIS-based techniques to integrate the urban heat island risk with the vulnerability of the population and other relevant local factors, covering 6 urban areas, including Genoa.
CLEAN AIR	SECAP and Genoa Lighthouse 2050	The action aims to pilot test a widespread, low-cost network of sensors capable of collecting data on air quality and allergens. It involves the development of apps for smartphones with direct communications on quality areas and routes with beneficial effects on health, and encourages better access and appreciation of urban spaces.
UNESCO SENTINEL	SECAP and Genoa Lighthouse 2050	This action aims to combine satellite monitoring and on-site sensors to calculate how air pollution and heavy rain affect the façades of the Palazzi dei Rolli and other UNESCO historical buildings. The intention is to develop a multilevel governance system able to improve the monitoring of the effects of climate change on architectural heritage.
RIV.eco	Genoa Lighthouse 2050	The action aims to review some municipal regulations to identify opportunities for updating and improvement, and to encourage the urban transformation and regeneration processes that are more in line with the recommendations of international agreements. Some of the expected improvements focus on: damage caused by strong storms and cloudbursts, prevention of risk related to fires and urban heat island phenomena, rational use of rainfall water, waste management according to circular economy principles, and use of functional greenery in the regeneration of urban spaces.

Data availability

The authors declare that all data are referenced within the article and publicly available online.

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