Good practices of adaptation to climate change: Sustainable Energy and Climate Action Plans implementation in Italy

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Abstract Adapting to climate change is a fundamental component within the Sustainable Energy and Climate Action Plans (SECAPs). In a context of increasing climate uncertainty, cities and communities must prepare to address the current and future impacts of climate change. SECAPs tackle adaptation through a series of specific measures and actions. First and foremost, a climate characterization of the examined territory is carried out, considering both the current situation and future short- and medium-term climate scenarios. Based on these assessments, a vulnerability analysis is conducted to identify specific climate-related risks that can influence the reference area. These risks may include extreme events such as floods, droughts, heatwaves, and more intense storms. The SECAPs then encompasses a range of actions aimed at reducing vulnerability and improving community resilience in the face of such risks. Adapting to climate change within a SECAP is a volunteer and dynamic process that requires long-term planning and ongoing evaluation of the adopted strategies. Cooperation among various stakeholders, including government entities, local institutions, communities, and the private sector, is essential to ensure effective adaptation and sustainable management of climate risks. The article will focus on SECAP development case studies about the following territories: Reno Galliera Union, Municipality of Vieste, Municipality of Cervia.

Introduction

The objective of this paper is to describe the outcomes achieved from the application of the Sustainable Energy and Climate Action Plan (SECAP) to three different contexts and the related workflow. The research work led to the identification of some of the main adaptation actions that can be considered to provide useful insights to practitioners and policy makers on adaptation strategies in different contexts of the Italian territory. The case studies are the reduction of surface runoff in Reno Galliera Union, coastal erosion and the resulting risk of flooding from the sea in the Municipality of Vieste, risk analysis of flooding due to sea-level rise in the Municipality of Cervia.

The case studies concern the Italian territory since Italy is in an area identified as particularly vulnerable to climate change. In detail, the latest reports on climate change show how Italy is particularly sensitive to the increased temperatures and reduction of water security under different aspects, from flood risk to drought, with repercussions in terms of safety of populations and exposed assets. These trends will have different impacts on specific territories (i.e., coastal areas, urban areas, mountainous areas, etc.), biodiversity and ecosystems, as well as the many economic sectors involved (e.g., agriculture, building, manufacturing, etc.) (Ali et al. 2022). In addition, differently from published works, the case studies cover small and medium-sized Italian municipalities as they represent the majority of municipalities and where the greater part of the population lives (> 68.5%) (ISTAT 2020).

The paper is structured as follows: the following chapter of Section 1 contextualizes the issue of climate change and the main tools adopted at community level to address it, Section 2 describes the method and workflow applied in designing the Sustainable Energy Action Plan while Section 3 shows the results of the application to three case studies differing in geographical location, municipality size and population involved. Finally, the main conclusions are highlighted in the last section of the document.

Background

It is well known that the fight against climate change requires concerted efforts from the global community on two main sides. While reducing and mitigating carbon emissions is crucial to slow down global warming, the effects of climate change are already happening in the form of an increasing incidence of extreme weather events and other similar trends, necessitating adequate adaptation measures. There are many intersections between mitigation and adaptation actions (Figure 1); however, the two streams of climate action have so far evolved largely independently from each other, and the interactions between them are still underestimated (Chapman & Stiff 2018).

Instead, tackling climate change requires an integrated and holistic approach that encompasses both mitigation and adaptation actions.

The European Environment Agency defines climate change mitigation as a set of actions aimed at making the impacts of climate change less severe by preventing or reducing greenhouse gas (GHG) emissions into the atmosphere. Mitigation is achieved by reducing the sources of these gases (e.g., by increasing the share of renewable energies or creating a cleaner mobility system) or enhancing their sinks (e.g., through expanding forests). In short, mitigation is a human intervention that reduces the sources of greenhouse gas emissions and/or strengthens the absorption wells.

These actions are crucial to slow down global warming and limit the future impacts of climate change. However, even if emissions were drastically reduced today, the effects of climate change would still be present due to past emissions and delays in the response of the climate system.

This is where adaptation to climate change comes into play. According to the European Environment Agency, "adaptation" means anticipating the adverse effects of climate change and taking appropriate measures to prevent or minimize the damages they can cause or seize the opportunities that may arise. Examples of adaptation measures include large-scale infrastructure modifications, such as building defences to protect against sea-level rise, and behavioural changes, such as reducing individual food waste. Essentially, adaptation can be understood as the process of adjusting to the current and future effects of climate change by adopting actions aimed at reducing the vulnerability and improving the resilience of communities, infrastructure, and ecosystems to the impacts of climate change. Adaptation is essential because the effects of climate change are already visible.

To achieve the goal of combating climate change, European adaptation policies have progressed quickly in recent years, with notable results such as the Paris Agreement, the 2030 Sustainability Agenda, the introduction of the European Green Deal, the new EU Adaptation Strategy, and the Climate Law of 2021.

The protection of the environment is now a fundamental principle of European Community, as already stated in Article 37 of the Charter of Fundamental Rights of the European Union (European Union Proclamation 2000). However, it thanks to the communication titled *The European Green Deal* (European Commission 2019) that the European Commission launched a new strategy aimed at transforming the Union into a prosperous society, equipped with a modern, resource-efficient, and competitive economy that will not generate net greenhouse gas emissions by 2050. The Green Deal has effectively marked a turning point for the planning of the community strategy for sustainable development, laying the groundwork for the publication of important regulations and directives aimed at decoupling economic growth from the improper use of natural resources and greenhouse gas emissions.

For example, consider the definition of EU Sustainable Finance Action Plan (EU Commission 2018), which has led to the classification of economic activities considered environmentally sustainable in the EU Taxonomy (European Union 2020), to support the transition to a low-impact economy not only with policy regulations but also from a financial point of view. As a matter of fact, the first two goals of Taxonomy Regulation concern mitigation and adaptation to climate change and are further elaborated in the Climate Delegated Act (EUD Regulation 2021), which

establishes under what conditions an activity is considered capable of contributing to the taxonomic objectives related to the climate, through Technical Screening Criteria.

It is undeniable, however, that climate change has several severe implications for other environmental issues. In fact, the European Climate Law (EU Regulation 2021), which establishes the framework for achieving climate neutrality, reflects the concerns of the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) to emphasize that climate change is the third most significant driver of global biodiversity loss.

The climate issue, far from being a confined topic, is part of the UN Agenda 2030 (UN General Assembly 2015), one of the main attempts to address the dimensions of sustainable development in a synergistic way, highlighting the mutual influences between environmental concerns, economic growth, and the well-being of people considered in its entirety. The SDG 13, through its five targets (United Nation), promotes the fight against climate change, integrating a strong component of awareness, education, and enhancement of global skills, both from a human and institutional perspective, in terms of mitigation and adaptation.

On the other hand, the new EU Strategy on Adaptation to Climate Change (EU Commission 2021) also highlights the close relationship between various risks associated with climate change - from the health of the planet and people to risks for infrastructure, supply chains, agriculture, and some of the major human activities. It calls for maintaining a high level of monitoring, starting with specific data. In particular: «Data on climate-related risk and losses are crucial to improve the accuracy of climate risk assessment. Any new investment and policy decision should be climate-informed and future-proof, from households renovating their homes, to SMEs setting up business in a vulnerable area, larger businesses managing supply chains, banks agreeing new loans, or cities planning zoning developments».

It is true that, in line with the scientific findings of the IPCC (Intergovernmental Panel on Climate Change) and the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services), achieving the goal of climate neutrality by 2050 requires not only reducing greenhouse gas emissions, but also increasing absorption. This is why Europe is committed to reducing Union emissions by at least 55% compared to 1990 levels by 2030.

Not less important is addressing adaptation adequately. As stated in the European Climate Law: «Adaptation is an essential element of the long-term global response to climate change. The adverse effects of climate change could potentially exceed the adaptive capacity of the Member States. Member States and the Union should therefore enhance their adaptation capacity, strengthen resilience, and reduce vulnerability to climate change, as provided for in Article 7 of the Paris Agreement, and maximize co-benefits deriving from other policies and regulations» (EU Regulation 2021).

Notably, the 2023 edition of the Global Risks Report, published by the World Economic Forum, ranks the failure of measures to increase adaptation to climate change as the second most significant global risk over a ten-year time frame. For this reason, it can be even more crucial to direct efforts towards greater resilience at the local level, because “the local level is the bedrock of adaptation” (European Commission 2021).

In this context, the Covenant of Mayors for Climate and Energy comes into play (EU Commission).

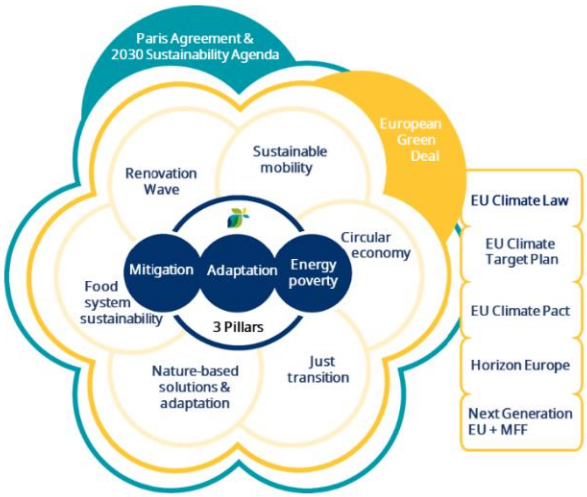

Fig 1. Covenant of Mayor classification activities (EU Commission).

Launched in 2008, it brings together thousands of local governments eager to ensure a better future for their citizens. By participating in the initiative, they voluntarily commit to implementing the EU's climate and energy objectives. The initiative not only represented the first bottom-up movement for climate and energy, but its success quickly exceeded expectations: since its launch in 2008, the initiative has mobilized over 10.000 local authorities in Europe, representing roughly one third of the EU population.

Local authorities that join the Covenant of Mayors - Europe commit to acting at the pace set by science, in a joint effort to keep the global temperature increase below 1.5°C - the updated target of the Paris Agreement. Covenant signatories commit to (1) reducing greenhouse gas emissions in their territory, (2) increasing resilience and preparing for the negative impacts of climate change, and (3) addressing energy poverty as a key action to ensure a just transition.

The success of this initiative and its ongoing evolution do not remove the complexity and problems of the Sustainable Energy and Climate Action Plan (SECAP) implementation (Delponte et al.2017).

The scientific literature shows that works focusing on European initiatives to combat the effects of climate change and on SECAP are not very abundant (Abarca-Alvanez et al. 2019). Most of them being focused on mitigation criteria, such as, for example, the correlation between reducing emissions by saving energy in buildings and increasing air quality (Monforti-Ferrario et al. 2018), the evaluation of emission reduction policies of a hundred cities with more than 100,000 inhabitants (Croci et al.2017), and the analysis of the results of a multi-municipality energy approach (Kamenders et al. 2017).

Other works have focused on the development of methodologies and tools to support the planning, implementation and monitoring process of SECAPs. They range

from the application of the International Standard ISO 50001 by municipalities to facilitate the implementation of their sustainable energy action plans (Dzene et al. 2015), to the development of monitoring methodologies to support the Public Administration (Cinocca et al. 2018) and tools for mapping the actual state of energy resources in order to develop sustainable energy policies (Gagliano et al. 2015). Case studies and SECAP applications are limited and mostly involve large metropolitan cities, e.g., Milan, Palermo, Rome and Genoa. (Berghi 2016; Kamenders et al. 2017).

At the same time, the ongoing increase in the signatories of the Pact and the fact that the majority of these signatories (67,38% of the whole CoM Signatories in April 2021) fall under the so-called 'small' municipalities (i.e., those with fewer than 10,000 inhabitants), is an encouraging fact. (Scorza-Santopietro 2021).

Work methods

The members of Covenant of Mayors for Climate and Energy - Europe initiative commit to submitting an action plan within two years of formal accession to the initiative. This action plan is a key implementation tool for Covenant signatories. It defines mitigation and adaptation objectives, and it is based on a Baseline Emission Inventory and a Risk and Vulnerability Assessment, which provide an analysis of the situation at a given time. They serve as a basis for defining a comprehensive set of actions that signatories intend to undertake to achieve their objectives, as well as to address energy poverty.

In practical terms, the Sustainable Energy and Climate Action Plan (SECAP) is structured into four different steps:

- Territorial characterization of the examined area.
- Analysis of vulnerabilities and risks for the relevant territory.
- Reconstruction of energy balances and emissions inventory.
- Proposal of actions for climate change mitigation and adaptation.

Territorial characterization of the examined area

Territorial characterization within the Sustainable Energy and Climate Action Plan (SECAP) is a process aimed at understanding the characteristics, resources, and potentials of the examined territory.

Territorial characterization should be based on data and information collected from various sources, including local administrations, environmental agencies, research institutes, national statistics, remote sensing tools, and specific studies conducted on the territory. The goal is to develop a comprehensive understanding of

the territory's characteristics to guide the development of a concrete action plan, tailored to local needs for the transition to a sustainable and low-carbon economy.

In the context of SECAPs, territorial characterization generally involves two subjects: the first aims to provide an overview of the territory, while the second focuses on the socio-economic context. In the first phase, a land use analysis is conducted, providing information on urban, rural, and natural areas present in the territory. Vegetation coverage, including the presence of forests or green areas, is an important factor for assessing the territory's capacity to absorb carbon emissions and mitigate the effects of climate change. Information on traffic and mobility in the territory is also collected during this first phase.

Territorial characterization also considers socio-economic aspects such as resident population, employment, dominant economic activities, and social dynamics. This provides a complete picture of territorial dynamics and the socio-economic implications of actions aimed at promoting sustainable energy.

Socio-economic and land use characterization of a territory are two of the main input data considered at the very beginning of the following phase: vulnerabilities and risks analysis.

Analysis of vulnerabilities and risks for relevant territories

Risk analysis helps to deal with potential threats and vulnerabilities associated with energy and climate change in territory. The objective of risk analysis is to identify and understand the potential negative impacts and consequences of actions or extreme weather events on the territory, as well as to identify opportunities to mitigate such risks.

The most important components for assessing and managing climate change-related risks are hazard analysis, exposure analysis, and vulnerability analysis (Field 2012).

Risk exists only when a hazard source, a target system (or vulnerable receptor) that can experience negative consequences, and exposure, meaning the possibility of contact between a hazard and the receptor, coexist in well-defined areas and time intervals. The vulnerability component, defined as the propensity or predisposition of a system to be negatively altered, encompasses sensitivity, which refers to the "susceptibility" to damage, and adaptive capacity. Adaptive capacity expresses the ability of a system (nation, community, group) to adjust its characteristics to present and/or future climatic conditions and reduce the level of vulnerability, in relation to specific dynamic contexts of a biophysical, social, economic, technological, and political nature.

The proposed risk and vulnerability analysis is conducted based on the bi-dimensional risk index presented and described in the National Plan for Adaptation to Climate Change (MASE 2018). The index combines "potential impact" (determined by hazard, exposure, and sensitivity) with adaptive capacity. Thus, the proposed

index includes the three fundamental components in risk assessment and management, but vulnerability is differentiated into sensitivity and adaptive capacity.

In this conceptual framework, vulnerability is partly quantified by territorial indicators (spatially distributed) that assess not only exposure, but also the greater or lesser propensity for damage and sensitivity (e.g., physical, geological, and land use characteristics). The other part is described by some adaptive capacity components, measured by indicators at the provincial level, regarding the greater or lesser ability of the territory to address climate change.

While in the broad sense, vulnerability encompasses both sensitivity and adaptive capacity according to the theoretical definition of the IPCC, in practical terms, sensitivity expresses the susceptibility to damage for each hazard separately, while adaptive capacity reflects the ability to deal with overall damage, i.e., the sum of the damages resulting from all considered hazards (Figure 2). For this reason, in calculating the risk index, sensitivity and adaptive capacity cannot be treated together (MASE 2023).

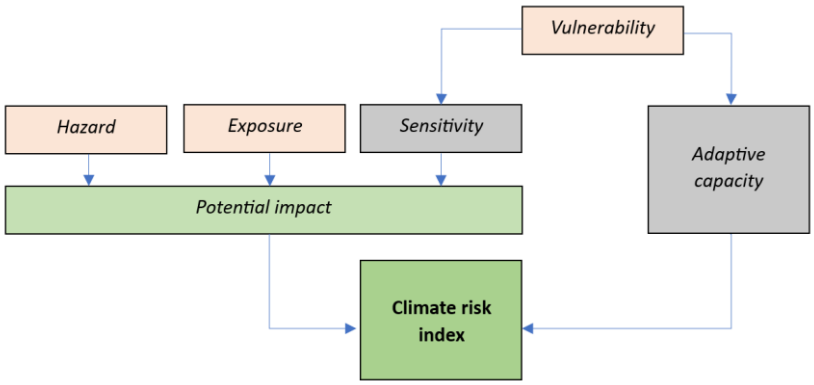

Fig 2. Climate risk index definition approach.

Therefore, the index reported in Figure 3, developed and detailed in the PNACC, in accordance with the IPCC guidelines, is configured as a bi-dimensional index (Potential Impact and adaptive capacity) presented at the provincial level, and it is an efficient tool for nationwide investigation.

It should be noted that, while the bi-dimensional index, based on parameters mainly derived from national or European databases, certainly provides a useful contextual analysis for a national plan, it should be further explored to identify and guide the implementation of specific adaptation actions at the local level (see the section "Proposal of actions for climate chance adaptation").

In other words, the bi-dimensional index proposed by the PNACC should be supplemented with the findings from SECAP phase 1 (territorial characterization of an area) to obtain a comprehensive map of risks and vulnerabilities in the studied territory.

In particular, the "hazard" parameter must be assessed through a series of indicators that serve as proxies for hazardous events, such as: landslides, heatwaves, floods, droughts, frost, flooding, fires, erosion, and water availability. Each

identified climate hazard has the potential to cause losses to human lives or health impacts, damage and losses to properties, infrastructure, services, and environmental resources. The guidelines for drafting the SECAP identify eleven sectors to contextualize the identified environmental impacts, including: buildings, transportation, energy, water, waste, land planning and use, agriculture, environment, health, civil protection and rescue, and tourism.

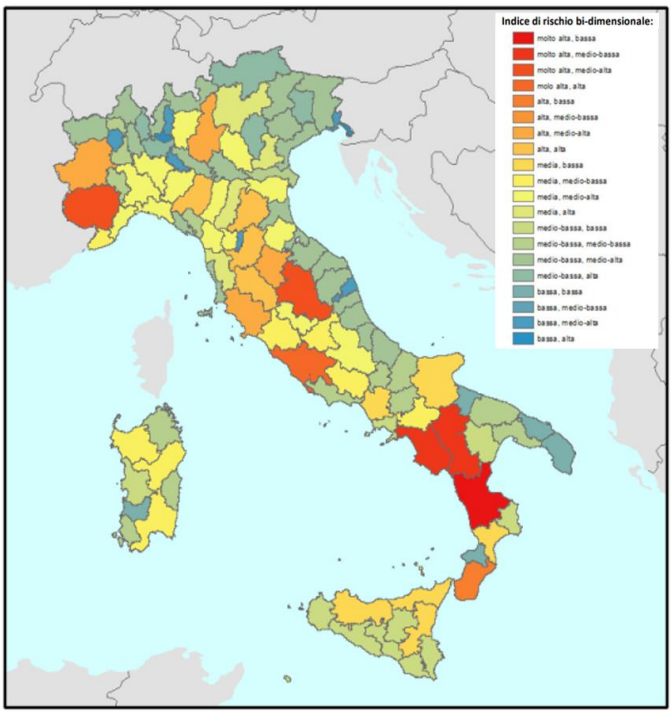

Fig 3. Vulnerability index of Italian districts according to PNACC.

Energy balance and emissions inventory

The energy balance within the Sustainable Energy and Climate Action Plan (SECAP) is an analysis that provides a detailed assessment of energy consumption and production in the considered territory. The energy balance is useful to define an energy baseline in the territory, identify the predominant energy sources, and evaluate opportunities to improve energy efficiency and promote renewable energy sources.

Following the JRC Guidelines (Bertoldi 2018) for the preparation of the Baseline Emission Inventory (BEI) and SECAP, the analysis is structured as follows:

- Energy consumption under the direct responsibility of the municipality, particularly related to its own building stock, public lighting, and municipal vehicle fleet.
- Energy consumption within the territory, which includes private building stock, tertiary sector, small and medium enterprises not covered by the Emission Trading Scheme (ETS), and urban transport.

Based on the findings of the energy balance, the BEI is prepared to establish a snapshot of the municipal energy situation in the reference year, to compare it with the current state. The BEI thus serves as the starting point for the SECAP, from which objectives can be defined, an appropriate Action Plan and following monitoring can be developed. The BEI quantifies the CO_2 emitted in the local authority's territory during the reference year in assessing the reduction commitments by 2030. To show the emissive trend of the territory, SECAP signatories must analyse a Monitoring Emission Inventory (MEI), starting from energy consumptions of subsequent years.

Proposal of actions for climate change adaptation

Adaptation strategies in the SECAP include a series of actions aimed at adapting to the impacts of climate change. Some of these actions can deal with reducing greenhouse gas emissions as well (i.e. forestation). Each action is associated with a specific SECAP sector. Since adaptation and mitigation strategies can vary depending on territory characteristics, available resources, and specific needs of local communities, it is difficult to standardize action proposals.

It is important to develop a customized SECAP that considers the specific challenges and opportunities of the considered territory, as identified in the territorial characterization and emissions inventory phases.

Case studies of adaptation to climate change

Three illustrative SECAPs adaptation case studies are presented below (Figure 4). They emphasize adaptation actions, particularly in the context of floods, as the main theme of this discussion. Specifically:

- **Reno Galliera Union**: Special attention will be given to actions related to the reduction of surface runoff.
- **Municipality of Cervia**: Adaptation actions are linked to coastal erosion and the resulting risk of flooding from the sea.
- **Municipality of Vieste**: Adaptation actions are related to the possibility of flooding due to sea-level rise.

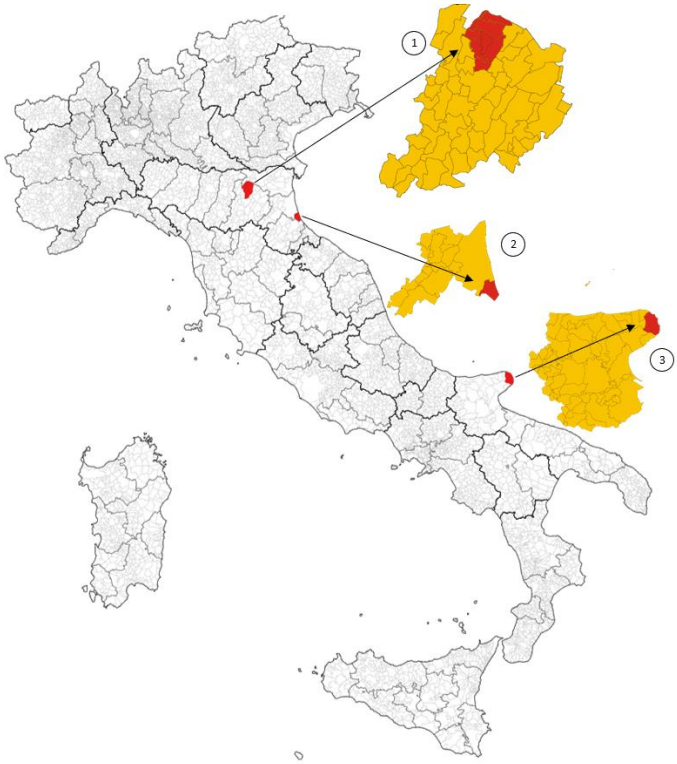

Fig 4. Localization (areas colored in red) of the case studies of adaptation to climate change within the Italian territory (Note: 1: Reno Galliera Union, 2: Cervia and 3: Vieste).

In addition to these, some of the main proposed actions related to other relevant issues for each territorial context will be reported. The summary of all adaptation actions, for each case study and sector of interest, is provided in Table 1. Every adaptation measure is associated with a Key Performance Indicator (KPI) which either is or can be used for monitoring the application of action itself in its territory.

Table 1. Adaptation measures listed by hazard, with each associated KPI, for each case study.

Case study	Hazard	Adaptation measures	KPI [SI units]
Reno Galliera Union	Increase of extreme precipitation events, which often lead to damaging floods and challenging drainage situations.	Reduction of surface runoff implementing: 1. construction of draining ditches alongside roads and parking lots 2. installation of infiltration wells 3. use of high-permeability pavements 4. de-pavement measures	Surface change in green & blue infrastructure [%] Surface change in waterproof pavement [%]
		Cleaning and maintenance of the main and secondary hydraulic networks (rivers, streams, canals, etc.)	Number and type of infrastructure on which adaptation interventions have been carried out
		Maintenance, improvement, or expansion, (including infrastructure upgrades) of the sewage system	Number and type of infrastructure on which adaptation interventions have been carried out
Municipality of Cervia	Costal erosion with the connected risk of sea flooding	Protection and restoration of the costal dune: 1. Placement of sand in front of the current dune face 2. Installation of windbreak fences (ganivelles) 3. Cover with dry plant residues spread on the ground to promote the deposition and capture of seeds and the development of new vegetation 4. Keep access to the dune area closed to prevent internal trampling; 5. Annual monitoring of the dune-beach system	Dune slope [°]. Reference values: 21°/25°. Before the intervention: 12°/15°. Presence of halo-nitrophic pioneer vegetation in the arenile area (community interest 1210), vegetation of embryonic and mobile dunes (community interest 2110), therophytic vegetation of dune mosaics (community interest 2230), vegetation of the gray dunes (community interest 2130), hygrophile vegetation back of the dune (community interest 6420), shrough vegetation back of the dune (community interest 2260) Georeferenced length, width and height of the dune [m]
Municipality of Vieste	Increased intensity of storm and the long-term risk of sea-level rise	Infrastructure improvements in the areas facing the sea and raising road levels	Number and type of infrastructure on which adaptation interventions have been carried out Coastal retreat [m]
		Demolition of unauthorized structures (8 interventions) and the development of paths and/or natural engineering works (7 interventions)	Number and type of infrastructure on which adaptation interventions have been carried out

Reno Galliera Union

The Reno Galliera Union includes a group of 8 municipalities within the metropolitan city of Bologna, Emilia Romagna (Italy). The union encompasses an area of 295,56 km² with approximately 74.000 residents (ISTAT). The analysis was conducted following the guidelines outlined in Chapter 2. The starting point was to conduct a detailed territorial analysis to identify the risks and vulnerabilities specific to the area under examination, as well as to compile the BEI. The results of this assessment demonstrate that heatwaves and intense precipitation are the climate hazards with highest level of risk. Furthermore, it is noted that in a short to medium-term scenario, there is an expected slight increase in the intensity of all specified climate hazards. As for the sectors to focus on, they have been identified as water management, buildings, agriculture and forestry, and territorial planning.

Agricultural Sector

The agricultural sector is largely affected by direct and indirect impacts of climate change. Rising average temperatures and heatwaves create stressful conditions for crops, a situation that can be exacerbated by water shortages due to drought. All these factors disrupt the normal course of crop cultivation. Additionally, crop yields can be significantly influenced by the progressive increase in extreme weather events (such as storms and hailstorms) that can damage the harvest.

Adaptation Measures. To facilitate adaptation to climate change in the agricultural sector, first of all, it is essential to conduct a strategic assessment regarding the choice of plant species to cultivate, taking into consideration the evolution of the local territory. Furthermore, the responsible management of water resources is highly relevant, aiming to promote techniques that reduce waste. To mitigate extreme events, where possible, protective structures and crop protection systems should be implemented (such as nets for hail protection or anti-insect nets). In addition to introducing specific agricultural practices, the optimal management of irrigation systems, the selection of crop species, and the expansion of organic and local farming (km0) are equally important. Supporting closed-loop farming enterprises and promoting private urban gardens are also significant. The communicative strategy is also important to make these solutions effective; this requires adequate information and training for those involved, the introduction of new management criteria and practices by industry associations.

Residential Sector

Urban areas are highly sensitive to the effects of climate change due to the concentration of population and exposed infrastructure. Furthermore, climate phenomena are increasing in frequency and intensity, resulting in growing impacts on people's health and comfort, with a decrease in overall quality of life.

Adaptation Measures. The microclimate inside buildings is influenced by both external building components and internal systems. Therefore, the proposed adaptation measures aim to encourage the implementation of cool roofs and pavements, horizontal green roofs (green roofs and rooftop gardens), and vertical greenery (green walls) in both private and public residential structures.

Water Sector

Among the primary risks associated with climate change in the Reno Galliera Union territory is the increase in extreme precipitation events, which often leads to damaging floods and challenging drainage situations (surface runoff). Surface runoff is directly proportional to land urbanization (land use) and inversely proportional to soil permeability. The municipalities of Reno Galliera Union are situated in an area with a medium to high land consumption and low permeability, hence they are in a high-risk area for surface runoff (Figure 5).

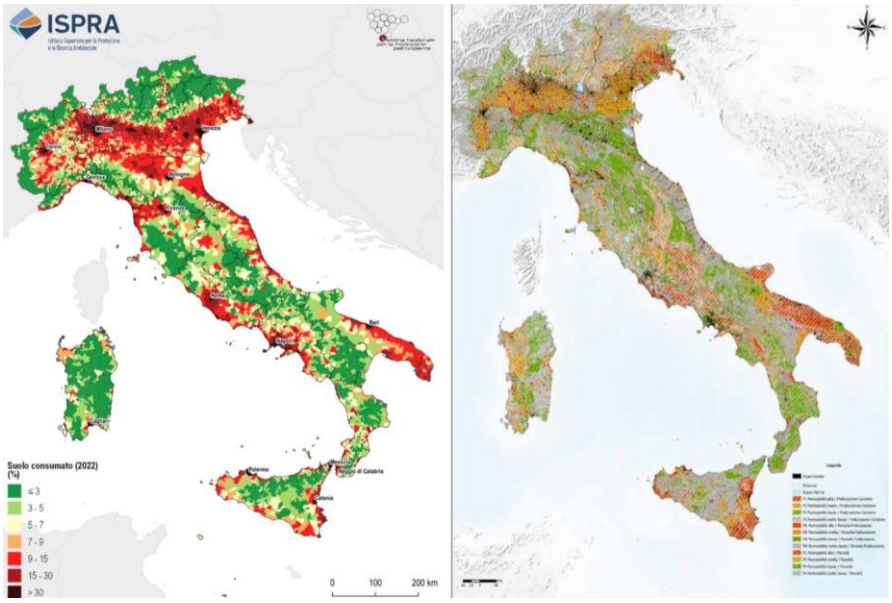

Fig 5. Right: Italy land use (by municipalities) (SNPA, 2023); Left: Italy soil permeability (ISPRA, 2023).

Adaptation Measures. To address this dual issue (surface runoff and damaging floods), it is possible to implement two different types of interventions. The first is

aimed at reducing the issue related to surface runoff, while the second focuses on reducing the risk of flooding. The surface runoff depends not only on the intensity of rainfall events, but also on the permeability of the soil and the capacity of the drainage network. In natural environments, rainwater is washed and slowly filtered by and through the soil. In urban environments, impermeable surfaces hinder the natural process of water infiltration, causing a rapid runoff toward final receiving systems. In case of extreme precipitations, excessive runoff and limited receptor capacity can lead to temporary flooding of urban spaces. Due to climate change, it is expected that extreme events will increase in intensity, putting additional pressure on urban drainage systems and exacerbating their inefficiency (Figure 6).

Regarding the surface runoff there are multiple possible adaptation actions, including: the construction of draining ditches alongside roads and parking lots, the installation of infiltration wells, the use of high-permeability pavements as replacements for traditional pavements (on roads and in parking areas), depaving and desealing measures, and, finally, incentives to increase the percentage of high-permeability areas (i.e., non-paved areas) within private properties.

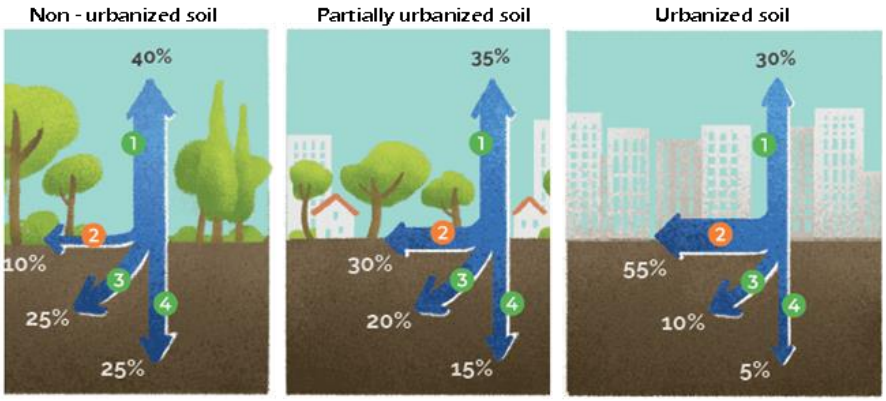

Fig 6. Rainwater infiltration process (1-Evotranspiration; 2-Runoff; 3-Surface infiltration; 4-Deep infiltration).

Simultaneously with actions to reduce surface runoff, both in terms of quantity and drainage time, there is a desire to implement measures to reduce the hydraulic risk in the territory. To move in this direction, the proposal is to enhance collaboration with competent entities for the maintenance of the main and secondary hydraulic networks (rivers, streams, canals, etc.) and for the planning and execution of interventions aimed at reducing the hydraulic risk in the area (Figure 7 represents an extreme event of flood). Furthermore, Reno Galliera Union intends to continue its collaboration with the sewage network management organization (HERA Spa) to carry out maintenance and improvement or expansion, including infrastructure upgrades, of the sewage system. This collaboration aims to reduce critical situations related to the insufficient drainage capacity of the network and enhance its resilience. This will be done in conjunction with an analysis of the vulnerability of the overall knowledge framework of the General Urban Plan (PUG).

Fig 7. Urban floods in Reno Galliera Union, May 2023.

Municipality of Cervia

Cervia is an Italian municipality located in the province of Ravenna, Emilia-Romagna. The adaptation actions undertaken for the Municipality of Cervia, in addition to aiming at the drafting of a SECAP are part of the Adriadapt project, "a Resilience Information Platform for Adriatic Cities and Towns," funded within the framework of the cross-border cooperation program between Italy and Croatia. The Adriadapt project aimed to support the construction of local and regional resilience by developing the necessary knowledge base to identify and plan appropriate options for adapting to climate change.

Territorial Planning Sector A

The analysis has outlined that the coastline near the dune area is characterized by strong erosion, most likely due to several factors, including high human activity, the presence of beachfront buildings and heavy use, various rigid elements disrupting coastal currents, cliffs and rocky outcrops, a significant decrease in the transport of sandy sediment from rivers, and improper management of vegetation and sand in the dune and beach area. Coastal erosion, which means loss of land along the coast due to the action of waves and tides, can lead to coastal flooding. When the coastline recedes due to erosion, coastal areas can become more vulnerable to flooding during storms or high tides. Waves can more easily penetrate inland, causing flooding in areas that were previously not subject to this type of event.

Currently, in Italy, a significant issue of coastal erosion is being observed. Approximately 60% of Italy's coastlines are affected by erosion, which can range in intensity from mild to severe. These coastal erosion phenomena pose a threat to the

marine and coastal environment as well as the communities residing in these areas (Figure 8). In particular, in the Emilia-Romagna region, located on the Adriatic coast of Italy, the coastal erosion rate is 31.4%, meaning that 31.4% of the region's coastline is undergoing erosion processes. This statistic is equivalent to a length of 44 kilometres of coastline affected by erosion. (ISPRA, 2018)

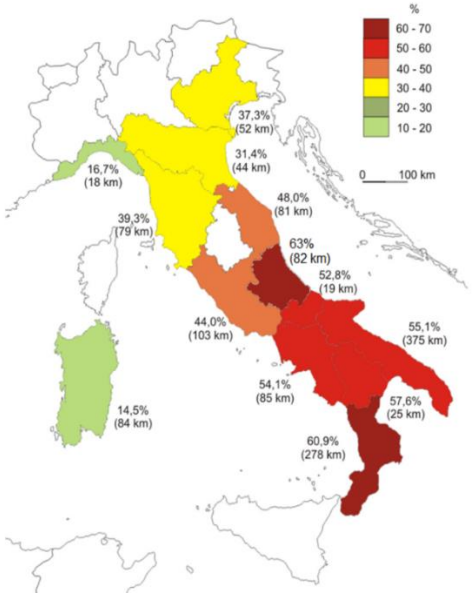

Fig 8. Costal Erosion in Italy (ISPRA 2018)

Adaptation Measures. Based on the considerations presented, a project for the protection and restoration of the dune has been planned. Considering the geomorphological challenges, the decision was made to create new conditions that favour the deposition and capture of sand carried by the wind, to achieve a dune body profile as close as possible to a natural profile, thus promoting the growth of native coastal vegetation.

1. The first intervention to be carried out is the placement of sand in front of the current dune face, to provide the current face with a new slope of approximately 23°/25° and thereby create the formation of a new dune toe with dry and mobilizable sand to cover the existing face, primarily composed of very compact and non-mobilizable shell-like sand. It was observed a slop of about 12°/15° before the intervention.
2. The second intervention involved the installation of windbreak fences (ganivelles) to facilitate sand capture and deposition. Windbreak fences were placed with a defense line in front of the new dune toe on the seaside, a line on the current dune ridge, and multiple lines inside erosion channels to restore lateral continuity of the dune body. In total, the project envisaged the installation of 635 linear meters of windbreak fences (ganivelles), with the placement of 287 chestnut support posts spaced at 1-meter intervals and one bracing stay per post on the seaside line, 165 chestnut support posts spaced at 1-meter

intervals and one bracing stay per post in the lines inside the blow-outs (erosion channels), and 92 chestnut support posts spaced at 2-meter intervals and one bracing stay per two posts on the inner line on the dune crest.

3. The parts of the dune which was loosing vegetation has been covered with dry plant residues spread on the ground, without excessive density, to promote the deposition and capture of seeds and the development of new vegetation.
4. It is of fundamental importance to not forbid access to the dune area, to prevent internal trampling, which promotes erosion, loss of vegetation, and the development of invasive and disruptive vegetation, all of which lead to an imbalance in the system and the onset of critical conditions.
5. Annual monitoring of the dune-beach system, according to the parameters listed in Table 1.

Fig 9. Left: dune-beach system in Cervia; Right: dune-beach ganivelles (Adriadapt Cervia project images by NIER Ingegneria).

Territorial Planning Sector

The conducted territorial analysis has highlighted an increase in average temperatures and heatwaves. To adapt to these climate hazards, proper territorial planning is crucial.

Adaptation Measures. The study carried out on the territory has emphasized the importance of sea breezes as local climate regulators. This is a phenomenon that must be considered in urban planning to avoid constructing built fronts along the coastline. Such constructions would have the undesired effect of obstructing the flow of air into the city, thereby increasing the likelihood of heatwaves.

Municipality of Vieste

Vieste is the easternmost municipality on the Gargano promontory and in the province of Foggia, Puglia (Italy) with a population of 13.459 inhabitants and an area of 169,19 km^2. Like the previous case, the analysis followed the same logical structure, highlighting that the most significant climate hazards (on which to focus the main adaptation actions) are droughts, fires, and heatwaves. Concerning a medium to long-term scenario, the risk related to storm surges and sea-level rise will increase. The sectors to concentrate on are the water sector, buildings, agriculture and forestry, civil protection and emergency services, and territorial planning.

Water Sector

One of the main risks associated with climate change in the municipality's territory is the increased intensity of storm surges and the long-term risk of sea-level rise.

Adaptation Measures. The Municipality of Vieste intends to undertake adaptation and enhancement measures, including infrastructure improvements, in the areas facing the sea to ensure safety, including the possibility of raising road levels. Among the actions already planned by the Municipality are the revitalization of "Enrico Mattei" and "Europa" Promenades. Additionally, SECAP includes the completion of the safety measures for the "Pizzomunno" Cliff and the protection of the rocky outcrop in the "Reginella" area (Figure 10). These actions will be combined with initiatives to restore sites with landscape and environmental value. The action, for example, will include the demolition of unauthorized structures (8 interventions) and the development of paths and/or natural engineering works (7 interventions).

Fig 10. Costone Reginella in Vieste.

Civil Protection and Emergency Services Sector

The forestry sector is significantly affected by both direct and indirect impacts of climate change. Particularly noteworthy are the number of wildfires in forested areas, mostly in protected regions.

Adaptation Measures. In this case, adaptation measures aim to enhance the maintenance of forested areas, such as clearing and deforestation of critical areas to create firebreaks. These actions will involve agreements with agricultural entrepreneurs. Additionally, the development of a municipal civil protection plan has been planned, including the management of the risk of forest fires.

Territorial Planning Sector

Among the primary risks associated with climate change in the municipality's territory, there is an increase in the intensity of storm surges, and in a medium to long-term scenario, the risk of sea-level rise.

Adaptation Measures. Adaptation measures will include actions to adapt and enhance the infrastructure along the coast to secure the area, which may involve raising the road level as well. Each specific intervention can be monitored according to the parameters listed in **Table 1**.

Conclusions

Since climate changes are at the basis of the sociological and demographic evolution of the world population, it is necessary to investigate the causes that originate them and convey the main environmental changes on our planet. The European sustainability objectives frame and dedicate a space to the issues of climate change mitigation (implementing preventive policies with respect to greenhouse gas emissions into the atmosphere) and adaptation to extreme climatic events (starting from the assumption that the changes themselves are now inevitable and their consequences on the population and on the environment in which they occur).

In this sense, the Sustainable Energy and the Climate Action Plans (SECAPs) play a decisive role as one of the main programmatic tools of the Public Administrations for planning both the aspects.

Since a comprehensive understanding of the areas to which adaptation processes can be applied is required, it becomes essential to study local characteristics and convey them to policymakers and technical offices. This will enable them to make informed and conscious decisions regarding the priority actions to be implemented. (Magni et al. 2020). At the same time, cities and municipalities are fundamental in pursuing sustainability, as they lead the local community in developing local policies and regulations that go beyond national targets; they encourage, for example,

energy efficiency in public buildings and promote sustainable products and services through green public procurement; and they share information with the local population about experiences and examples to improve knowledge and awareness regarding climate change. (D'Onofrio et al. 2023) This aspect enhances resilience at the local level, not only from an environmental perspective, but also in terms of social relationships, thanks to increased trust between institutions and the population.

With regard to adaptation to climate change, although there is no consolidated literature and case studies such as for the issue of mitigation, there are already several examples of how a territory, starting from the initiatives of its administrative policy, can implement practices that would have been seen as innovative in the past, but which are currently a necessary condition for guaranteeing a multi-year vision, and not just an emergency one, of the planning of the activities of a territory.

Despite some difficulties in applying the SECAPs and the related actions, for example the voluntary nature of the instrument, which is therefore not widely applied throughout the national territory, and the difficult coexistence with other territorial planning tools (for example urban planning), there is no evidence that the regulatory obligation has led, in the past, to greater awareness on the topic of adaptation to climate change. Therefore, it is believed that, in line with the emerging trends of the European taxonomy and consistently with the main initiatives on sustainability, both in the public and private sectors, the voluntary instrument, such as SECAPs, can be equated with regulatory obligations, not only for the rules that the municipalities decide to adopt, but also for the assumptions that the study behind SECAPs reports can originate.

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