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# Climate change adaptation cycle for pilot projects development in small municipalities: The northwestern Italian regions case study

Guglielmo Ricciardi<sup>a,b,\*</sup>, Marta Ellena<sup>a</sup>, Giuliana Barbato<sup>a</sup>, Giuseppe Giugliano<sup>a</sup>, Pasquale Schiano<sup>a</sup>, Sara Leporati<sup>c</sup>, Claudia Traina<sup>c</sup>, Paola Mercogliano<sup>a</sup>

<sup>a</sup> Regional Models and Geo-Hydrological Impact Division, Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC), 81100 Caserta, Italy

<sup>b</sup> Polytechnic of Turin, Department of Architecture and Design, 10125 Torino, Italy

<sup>c</sup> Fondazione Compagnia di SanPaolo, 10128 Torino, Italy

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## ABSTRACT

More than half of the European population live in small and medium size municipalities, where climate adaptation planning is an under-researched topic within the climate change field. Many constraints might hinder the implementation of adaptation pilot projects due to lack of economic, knowledge, and technical available resources. Local institutions find difficulties in building a coherent local adaptation planning and design processes with international and national frameworks. In this context, this article proposes a methodology based on the available international frameworks to support the small communities with the aim to implement adaptation pilot projects within different sectors. In doing so, this paper tests a climate change adaptation cycle for pilot projects development in small municipalities; the first in Italy for small municipalities under 20.000 inhabitants. The proposed methodology could lead local adaptation initiatives in climate change risk assessment by supporting the research communities in developing a coherent vision for the local territories and to identify proper oriented measures to enhance demonstrative pilot projects and to increase the level of resilience in small municipalities, avoiding maladaptation.

## 1. Introduction

Climate change impact is one of the key risks that can affect human society at the global level, and its effects vary significantly among different geographical areas and territorial scales [1]. By looking at human settlements, the exposure levels differ also in relation to the observed and expected local climate hazards, such as extreme temperatures and precipitation events, droughts occurrences, and sea level rise. In addition, the adaptive capacity, which entails preventive policies and measures at the local scale, can mitigate those risks. This is the reason why local municipalities are considered a key actor to develop adaptation policies and support local actions to increase the level of resilience [2]; Phil & Cohen, 2019; [3]). By looking at European territories, even if cities are one of the main hotspot of the climate change impacts due to a multiplicity of aspects, around 56 % of the population is located in a small or midsize town[4,5]. Small and medium-sized municipalities are

equally affected by climate change with very specific associated challenges and, to date, they are not so well represented in the research such as cities and metropolitan areas[6,7] (see Fig. 1. As emerged by the state-of-art literature, small towns present relevant different challenges compared to large urban contexts. For instance, they usually have to deal with a lower availability of climate data and information, scarce financial resources to implement adaptation measures and to develop technical and professional skills and a lack of governmental structures to additionally integrate climate change adaptation into their administrative practices[2,8–14]. In the Bavaria region (Germany), Bausch et al. [8] analyzed the implementation of mitigation and adaptation measures in small municipalities, and have identified significant gaps between theoretical discussion, local policies and concrete measures on the ground in the majority of small municipalities. Studies on small and medium municipalities present exceptions that have focused in particular on developing countries and the effects of climate change such as

\* Corresponding author at: Regional Models and Geo-Hydrological Impact Division, Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC), 81100 Caserta, Italy.

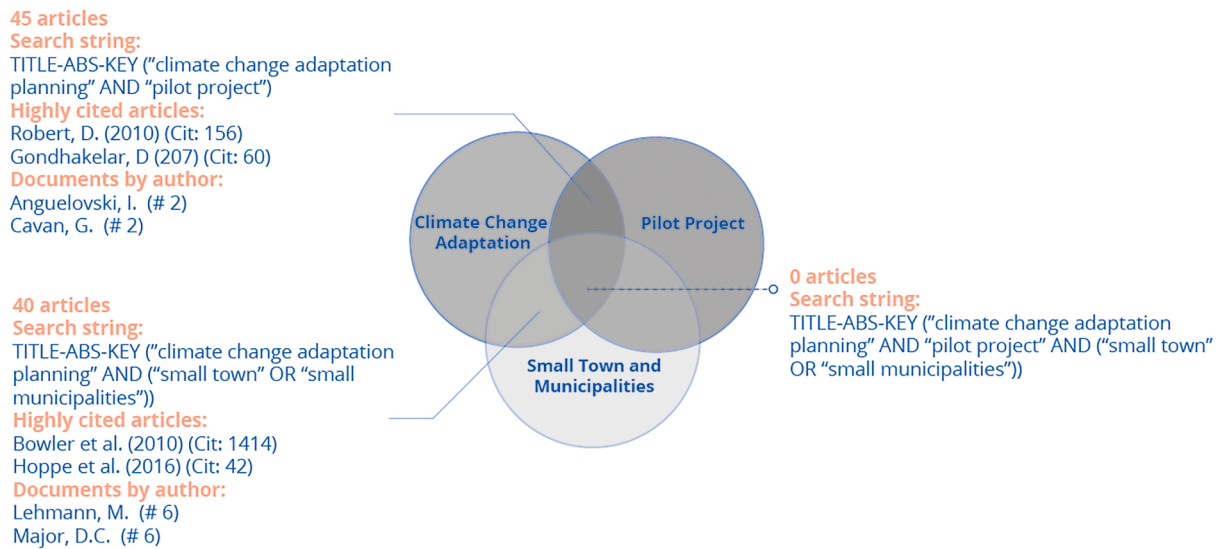
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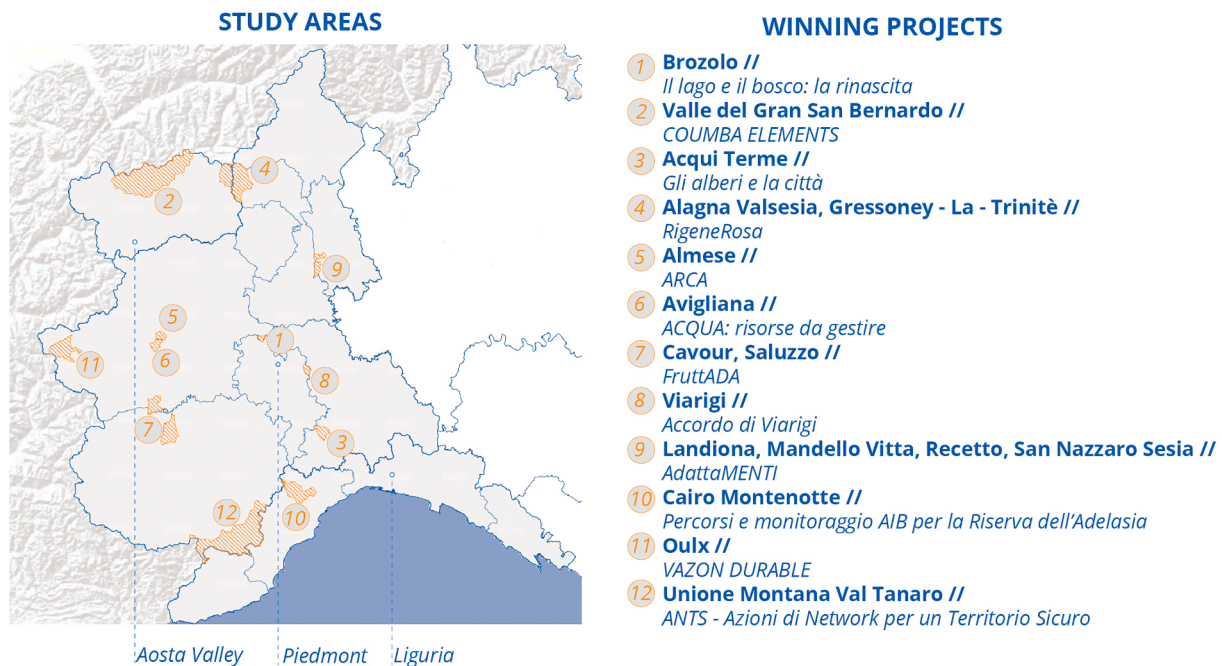
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**Fig. 1.** The intersections among Climate change adaptation, pilot projects and small Town and municipalities. Elaboration from studies extracted by Scopus database.



**Fig. 2.** The winner projects of the Call "Mutamenti".

sea level rise, flooding and landslides[2,10,15,16]. In addition, another exception focus on the possibility to develop climate change adaptation networks to exchange information and support the local communities [17].

Since 2015, in Europe, the main initiatives to support small municipalities in climate adaptation planning processes have been based on voluntary adhesion. Among others, Mayors Adapt integrated mitigation actions with climate risk assessments (i.e., adaptation defining a transition from Sustainable Energy Action Plan to Sustainable Energy and Climate Action Plan (SECAP)).

Therefore, in accordance with the highlights mentioned above, the research question is the following: which is the best strategy to support small European municipalities to cover technical and implementation issues related to climate change adaptation pilot projects development?

According to this question, this paper explained a applied hybrid

methodology (i.e., quantitative and qualitative approach), which could support local governments and stakeholders - within 12 small municipalities (with population under 20,000 inhabitants) in Piedmont, Valle D'Aosta and the Ligurian hinterland (northwest of Italy). This heterogeneous sample of case studies was identified to promote the northwest territories in Italy, as a laboratory to experiment a climate change adaptation cycle for local development in small municipalities. This with the aim to overcome technical and knowledge gaps in developing climate change adaptation pilot projects.

In doing so, the paper is organized as follows. Section 2 is oriented towards the contextualization of the case studies under consideration. And, while Section 3 describes in detail the theoretical framework and the applied methodology, Section 4 explores the obtained outcomes of each applied step and explores the capacity to address the main challenges involved in the adaptation processes at the local scale.

**Table 1**  
Detailed description of the winning pilot projects of Call “Mutamenti”.

N°	Proposing entity	Location of intervention and number of inhabitants	Project description
1	Amici dei Sentieri	Municipality of Brozolo: 450 inhabitants.	<b>The project aims to restore and safeguard a wooded area upstream and an artificial lake downstream of a hilly area.</b>
2	Associazione Pourparler	Unité des Communes valdôtaines Grand-Combin: 11 municipalities covering 437 square kilometers with around 6,000 inhabitants.	<b>Coumba Elements is an integrated and interdisciplinary project aimed at creating a Charter of Values (expression of local knowledge) and good practices to combat climate change impacts in mountain areas.</b>
3	Municipality of Acqui Terme	Acqui Terme, considered the main center of the Alto Monferrato, has a total surface area of 3325 (ha), with 19,845 inhabitants.	<b>The project envisages the possibility of increasing the green areas of the municipal territory through the creation of new green spaces, paying particular attention to self-cotton tree species that have a greater capacity to remove gaseous pollutants.</b>
4	Municipality of Alagna Valsesia	Alagna and Gressoney, two municipalities in the north-western Alps: populated by around 730 and 325 inhabitants respectively.	The project aims at a functional recovery of the existing structures, to adapt the site and the spaces of the old cableway to the new climate change adaptation needs.
5	Municipality of Almese	Municipality of Almese: about 6,400 inhabitants.	The objective of the project is to increase the resilience of the urbanized and infrastructural areas of the Municipality of Almese against extreme rainfall events through the adoption of adaptation measures related to the principles of Nature Based Solutions (NBS).
6	Municipality of Avigliana	The municipality of Avigliana has a population of about 12,500 inhabitants.	The project idea intends to act on the saving of water resources and on the mitigation of the geo-hydrological impacts of rainwater through activities to raise the awareness of the population and by intervening with works and infrastructures.
7	Municipality of Cavour	The municipalities of Cavour and Saluzzo are located respectively in a flat and semi-flat area to the south-west of the Piedmont regional capital: 5,473 and 17,423 inhabitants respectively.	The FruttADA Project originates from local processes of knowledge and operation e, with the aim of developing the resilience of the territorial fruit-growing system in the medium-long term.
8	Municipality of San Nazzaro Sesia	The area covered by the AdattaMENTI project concerns four municipalities (i.e., San Nazzaro Sesia, Recetto, Landiona and Mandello Vitta) with a total of 2,430 inhabitants.	The project represents the experimentation of a transformation process for the participatory management of the territory. Given the size of the territory involved, this project aimed to be a social and environmental

**Table 1 (continued)**

N°	Proposing entity	Location of intervention and number of inhabitants	Project description
9	Municipality of Viarigi	The Municipality of Viarigi belongs to the Province of Asti: inhabited by 855 residents.	laboratory to produce good practices that can be replicated in similar territories. The project idea took its cue from the need to recover abandoned areas, with the desire to return to managing them to cope with the increasingly frequent climate changes that lead to problems of a geo-hydrological nature and loss of biodiversity. The main objective was the creation of a <b>Land Association</b> , which will be the entity in charge of managing these lands.
10	Province of Savona	The Adelasia Regional Nature Reserve, entirely located in the Bormida Valley in the territory of the municipality of Cairo Montenotte, contains 12,729 inhabitants. i	The aim of this project is to protect the forest heritage of the Adelasia Regional Nature Reserve which is increasingly at risk of fire, due to the changes in progress and those expected in the climatic conditions of the area.
11	Società Meteorologica Italiana Onlus	Municipality of Oulx: 3,334 inhabitants.	The project aimed at creating awareness and resilience on climate change in the Alpine environment.
12	Tanaro Valley Mountain Union	A valley suspended between two regions and dominated by the Ligurian Alps, which, despite their name, mostly extend into Piedmont. 10 municipalities are involved: Alto, Bagnasco, Briga Alta, Caprauna, Garessio, Nucetto, Ormea, Perlo and Priola. Inhabitants number: 7.088	The project envisages the remuneration of local companies for land management actions aimed at preventing geo-hydrological instability.

## 2. The case study: Call “Mutamenti”

In recent years, foundations are playing a key role to support local, environmental and sustainable projects[18]. In this context, Compagnia di San Paolo Foundation (CSP) isa foundation located in the North West of Italy and, in the last years, it has developed several initiatives to promote the cultural, economic and environmental local development. In 2021, the CSP, in collaboration with the Foundation Euro Mediterranean Center on Climate Change Foundation (CMCC), launched the Call for Ideas “Mutamenti”, to promote and increase the resilience to the impacts of climate change over Piedmont, Valle D’Aosta and the Ligurian hinterland. In particular, the objectives of the Call were the following: (i) to foster a better understanding of observed and future climate change phenomenon; (ii); to increase awareness of the impacts of climate change based on data and risk assessment and management; (iii) to disseminate framework of global, European and national strategic policies on adaptation, and on the project funding opportunities arising from these policies; (iv) to encourage territories in the design of adaptation actions at the local level; and (v) to support the design and the implementation of specific adaptation measures in relation to each of the projects involved in the first and in the second phase of the call “Mutamenti”.

**Table 2**

Detailed analysis of climate change adaptation plans and policies development in the small municipalities test cases. Results extracted from the Covenant of Mayors database.

Proposing entity	municipalities	Sustainable Energy Action Plan (SEAP)	Sustainable Energy and Climate Action Plan (SECAP)
Amici dei Sentieri Associazione Pourparler	Brozolo	x	x
	Allein	x	x
	Bionaz	x	x
	Doues	x	x
	Etroubles	x	x
	Gignod	x	x
	Ollomont	x	x
	Oyace	x	x
	Roisan	x	x
	Saint-Oyen	x	x
	Saint Rhémy - en -bosses	x	x
	Valpelline	x	x
	Acqui	x	x
	Municipality of Acqui Terme	Alagna Valsesia	x
Gressoney la Trinitè		x	x
Municipality of Almese	Almese	x	x
Municipality of Avigliana	Avigliana	v	x
Municipality of Cavour	Cavour	x	x
	Saluzzo	v	x
Municipality of Viarigi	Viarigi	x	x
Municipality of San Nazzaro Sesia	Landiona	x	x
	Mandello Vitta	x	x
	Recetto	x	x
	San Nazzaro Sesia	x	x
Province of Savona	Cairo	v	x
	Montenotte		
Società Meteorologica Italiana Onlus	Oulx	x	x
Tanaro Valley Mountain Union	Alto	v	x
	Bagnasco	v	x
	Briga Alta	v	x
	Caprauna	v	x
	Garessio	v	x
	Nucetto	v	x
	Ormea	v	x
	Perlo	x	x
	Priola	v	x

With this initiative, CSP addressed the issue of climate change with an experimental approach aimed at local adaptation design initiatives, developed through community and territorial partnership. The pilot selection criteria of the “Mutamenti” Call were based on the territories description, clarity in submitted paperwork, the consistency of the project with the objectives of the Call, the potential effectiveness of the climate adaptation proposal; the adequacy and quality of the design community engagement strategy; and, finally, on the basis of financial criteria. Overall, 12 projects were shortlisted out of a total of 41 among Aosta Valley, Piedmont, and Liguria territories. The selected projects relate to different entities, such as municipalities, NGO local associations, union of municipalities and provinces, (Fig. 2 for more details). To provide a greater understanding of the characteristics pertaining to the projects, Table 1 explains the proposing entities, the location, the number of inhabitants, and the detailed description of each project. Given their geographical location, the identified territories in Piedmont, Liguria and Aosta Valley are subjected to different climate hazards which cause relevant impacts on different strategic sectors, such as on residents, infrastructures, agricultural activities, tourism, and on natural resources [19]

### 3. Methodology and data

#### 3.1. Theoretical background

There is no intermediate methodology to support the implementation of pilot projects for adaptation to climate change, with a particular focus on small municipalities that have not yet implemented plans and adaptation strategies and are characterized by the above-mentioned criticalities. The small municipalities used as test cases haven't developed SECAP plans (Table 2).

While adaptation is urgently required, the actual implementation of adaptation measures in the human settlements has been slow and insufficient [1,20–22]. The integration of climate change adaptation into existing policies and practices (i.e. mainstreaming), is widely seen as a promising way of achieving and accelerating climate resilience [23,24].

Climate change adaptation cycle has been characterized in the last years by many approaches in order to support national, regional and local authorities that focus more to develop plans and policies, such as the framework proposed by UNFCCC and inherited also by the “Adapting to Climate change in Time (ACT)” project [25]. The framework proposed by UNFCCC [26] considers the entire process to support the policies development at different scales, but does not look at climate change adaptation pilot project development. Recently, the European Commission [23], has developed guidelines to support the assessment of infrastructural projects to understand the impacts to climate change and how the new works will be affected by the effects of climate change. The method proposed by the European Commission [23] considers the infrastructure project assessment in terms of mitigation and adaptation, without dealing with the creation of knowledge, the capacity building of stakeholders, the identification of the critical points in terms of finance and capacity building. The European project LIFE LOCAL ADAPT focused on the integration of climate change adaptation into the work of local authorities, in particular to support this challenge in small to medium-sized municipalities. As reported in Weber et al. [7], the methodology adopted in the project aimed to improve data and information ground to climate change impacts, enhancing the knowledge of municipalities on climate change adaptation and mainstreaming of this approach into administrative practices of local authorities are the key factors under-explored in research practices. The project hasn't developed a coherent risk assessment of the effects of climate change in line with the IPCC framework. In December of 2021, another European project, named LIFE Adaptate focused on the design of a “Common methodology for the development of Sustainable Energy and Climate Action Plans in European municipalities”, through the implementation of pilot projects aimed to demonstrate the positive impacts of pilot actions related to mitigation /adaptation at local level and at the identification of the different approaches to use to address similar risks in local authority areas across Europe.

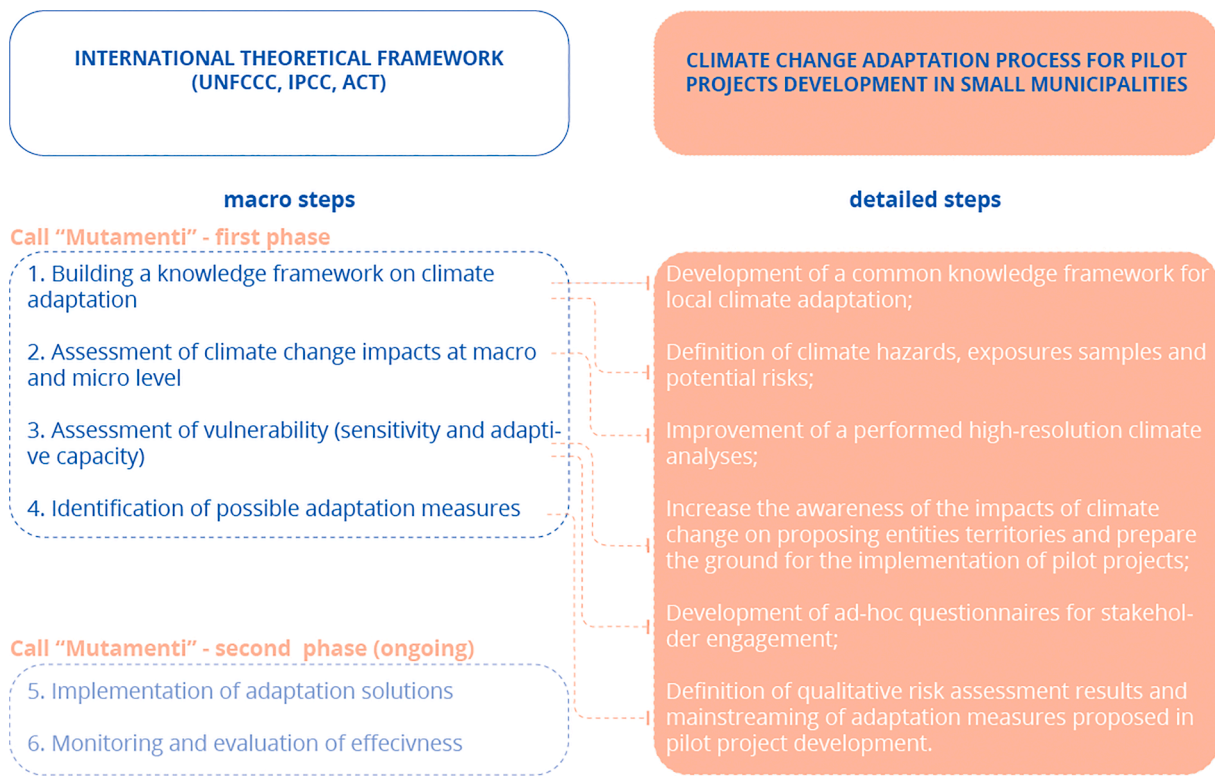
Climate Transition Strategy was proposed by Litt et al. [18], to support the urban planning project development of 4 small and medium municipalities based on the UNFCCC framework for climate change adaptation.

Until now studies and research projects have developed partial methodologies that consider only some aspects useful to support pilot projects for adaptation in contexts of small municipalities.

#### 3.2. Methods to accompany the development of design solutions considering the theoretical framework above described

The methodology tested in the Call “Mutamenti” is based on the theoretical framework for local climate change adaptation [25,26] and on the IPCC defined climate change risk assessment [4].

The methodology conceptualized in this study was articulated in six main steps (see Fig. 3 for further details):



**Fig. 3.** The main steps of the Climate Change Adaptation cycle for pilot projects development in small municipalities compared to the international framework for climate change adaptation.



**Fig. 4.** The chronological order of steps developed in the Climate Change Adaptation cycle for pilot projects development in small municipalities methodology for the Call "Mutamenti".

1. The development of a common knowledge framework for local climate adaptation through individual meetings with each proposing entity guided by CSP and CMCC. Here, the proposing entities explain the details of the design proposal (depending on the fact if the climate adaptation pilot project involves hard or soft actions), while CMCC has organized co-participation meetings to sensitize the stakeholders involved on the process of climate risk assessment.
2. The definition of the climate hazards, of the exposure samples, and of the potential risks. Once each proposing entity described the objective, the observed climate impacts, and the contents of the project, CMCC built a matrix characterized by the possible exposure sample (e.g., human settlements, infrastructures, tourism, agriculture, natural settlements) and consequently the climatic hazard that had to be analyzed in relation to the exposed sample and the possible characteristics of susceptibility and adaptive capacity that characterize the exposed sample.
3. The improvement of a performed high-resolution climate analyses during the early stage of the project, to determine the distribution of climate hazards in the different project areas: defining the used climate regional models, the spatial resolution, the Representative Concentration Pathways (RCPs) scenarios of IPCC, and the indicators used depending on the type of exposure sample and on the geographical context (e.g., urban, mountain, plain, hill).
4. In parallel, the winning pilot projects supported by CMCC structured and implemented activities aimed at:

**Table 3**

Detailed description of the impacts perceived by local communities and the synthetic risk identified by CMCC useful for the next steps.

N°	Proposing entity	Climate Hazard	Exposed sample (i.e., exposure)
1	Amici dei Sentieri	Fires, drought, geo-hydrological risk and flooding	Natural settlements (forest and lake)
2	Associazione Pourparler	Climate hazards for mountain areas (snow reduction and increase in temperatures)	Small village, winter and summer tourism
3	Municipality of Acqui Terme	geo-hydrological risk and flooding	Population, built environment and infrastructures
4	Municipality of Alagna Valsesia	Increase in temperatures and climate hazards for mountain areas (snow reduction and increase in temperatures)	winter and summer tourism
5	Municipality of Almese*	geo-hydrological risk and flooding	Population, built environment and infrastructures
6	Municipality of Avigliana	geo-hydrological risk, flooding and drought	Population and agricultural system
7	Municipality of Cavour*	Climate hazards related to fruit and agricultural system	Agricultural and Fruit system
8	Municipality of San Lazzaro Sesia	Increase in temperatures, geo-hydrological risk and flooding	Built environment and agricultural system
9	Municipality of Viarigi	geo-hydrological risk and flooding	Built environment and wine sector
10	Province of Savona	Drought, increase in temperatures, geo-hydrological risk and flooding	Natural settlements (forest) and winter and summer tourism
11	Società Meteorologica Italiana Onlus	increase in temperatures, geo-hydrological risk, flooding and climate hazards for mountain areas (snow reduction and increase in temperatures)	Small village, winter and summer tourism, agricultural system
12	Tanaro Valley Mountain Union	geo-hydrological risk and flooding	Population, Built Environment and Infrastructure

- raise awareness on issues related to the impacts of climate change, more specifically on the climate hazard most relevant to them;
  - structure “training meetings” to raise awareness within the entities operating in the system of interest of the project;
  - lay the groundwork for implementing pilot actions within the target territories.
5. The development of ad hoc questionnaires (based on the initial material proposed by each entity) structured by CMCC. This in order to collect information to include and present within the qualitative risk assessment reports (with specific indicators of exposure and vulnerability), useful for the proposing bodies both to better understand the variables of interest on which to work and to use these reports as dissemination material.
  6. The dissemination of the quantitative and qualitative risk assessment results through reports and the upload on the DataClime platform, as a tool to support the pilot projects stakeholder in the project development.

Each of the six steps have been replicated for the 12 pilot projects to ensure the test of the methodology in different contexts and for different sectors.

The six steps required several months to complete the entire process (see Fig. 4), and were validated by the stakeholders (i.e., municipalities, local institutions, and associations) and by the scientific and technical

support (i.e., CMCC).

### 3.3. Improvement of a performed high-resolution climate analyses

Basic element for the methodology implemented is availability of local climate profile. This analysis is performed to determine the expected features of atmospheric hazards for the different pilot project areas as a starting point for assessing adequate adaptation process.

Detailed climate hazard assessment represents an indispensable step to assess climate related impact evaluation on natural resources and on the various socio-economic sectors, as well as for a next assessment of sectoral vulnerabilities. In this work, the index-based approach has been adopted as it represents an operational solution widely used in the literature for supporting climate hazard assessment and the evaluation of the risk, providing information in terms of frequency, intensity, and persistence of weather-induced processes (EEA, 2018; [27,28]). The approach of using climate indicators for hazard assessment is largely adopted [29,30] and many studies have also shown the importance of using tailored indicators that take into account the local context [28,31].

## 4. Results

Climate Change Adaptation cycle for pilot projects development in small municipalities intends to promote the diffusion of a common approach linked with the international frameworks, through the support of concrete design and governance pilot project aimed to diffuse demonstrative interventions capable to generate a multi-level scale and institutions benefits, increasing the possibility to share information and learn issues linked to climate change between different stakeholders (Public Administrations, Associations and private sectors).

This chapter describes the results obtained by the proposed methodology to support small European municipalities to cover technical and implementation issues related to climate change adaptation pilot projects development.

### 4.1. Development of a common knowledge framework for local climate adaptation

The results obtained by the first step of the proposed methodology has consisted in:

- the presentation of the objectives of the winning design pilot proposal by the small communities stakeholders to CSP and CMCC, underlining the vision of the project, the observed climate change impacts detected by the local communities in the last years, and the possible adaptation pilot measures that the partners of each project would implement in the next periods;
- the description of factors and steps necessary to structure a preliminary mixed quantitative and qualitative risk assessment framework aim to define a common ground in terms of concepts and taxonomy with the pilot projects entities and local stakeholders and to evaluate the capacity of each design proposal to face to the effects of climate change (made by CMCC);
- the identification of the possible potential risks identified with the support of CMCC for each pilot project proposal.

### 4.2. Definition of the climate hazards and of the exposures samples

The second step of the proposed methodology has been conducted to identify the climate hazards that affect the territories of each entity in order to define the indicators that will be calculated in the next step through observed and future climate models. At the same time, after the preliminary meeting, it was crucial to identify the exposure sample for each territory analyzed based on the climate impacts perception presented by the stakeholders of each pilot project proposal. The main climate hazards identified for small municipalities are related to fires,

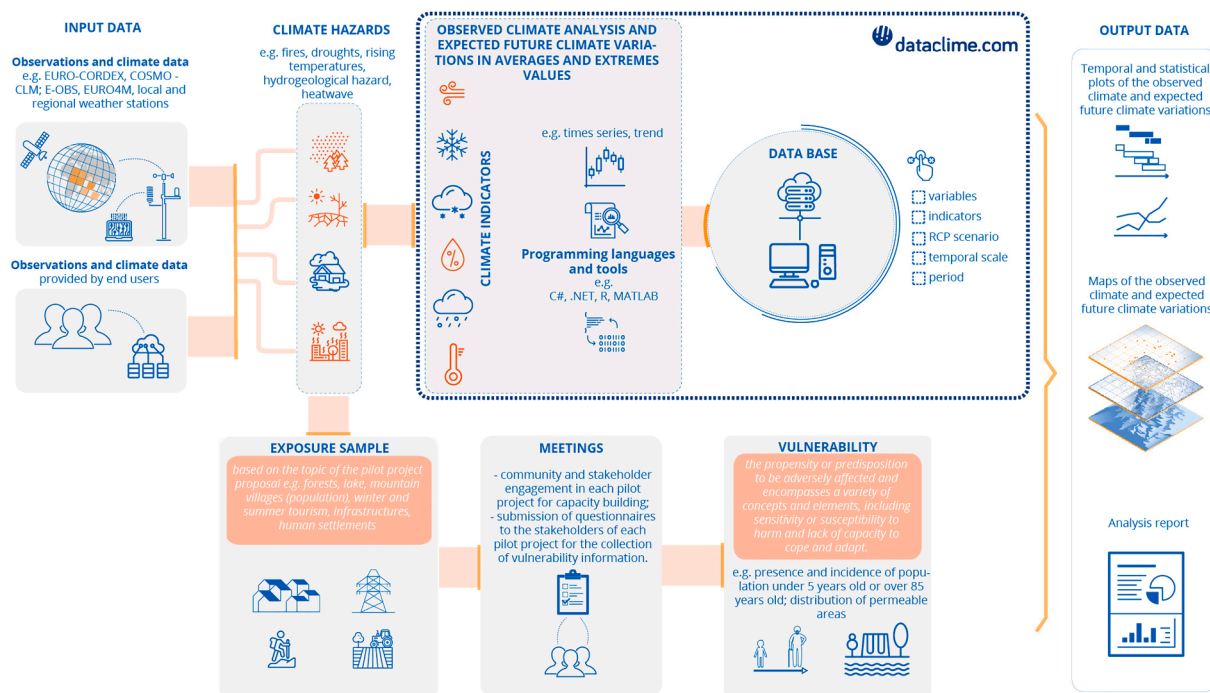


Fig. 5. The Climate Change Adaptation cycle for pilot projects development in small municipalities methodology for climate hazard analysis and for sharing the information through the Dataclime platform.

Table A1

List of the climate hazards tailored indicators for each project.

Hazard type	Indicators	Identification number of the project												
		1	2	3	4	5	6	7	8	9	10	11	12	
Fire- drought	CDD	x											x	
	WD	x											x	
Hydro-geological hazard, floods, decrease in rainfall	PRCPTOT	x		x		x	x		x	x	x	x	x	x
	RX1DAY	x		x		x	x		x	x	x	x	x	x
	RX5DAY	x		x		x	x		x	x	x	x	x	x
	SDII	x		x		x	x		x	x	x	x	x	x
	R10	x		x		x	x		x	x	x	x	x	x
	R20	x		x		x	x		x	x	x	x	x	x
	TR10PR	x		x		x	x		x	x	x	x	x	x
	TR100PR	x		x		x	x		x	x	x	x	x	x
Increasing temperatures	RR1	x		x		x	x		x	x	x	x	x	x
	TNN				x				x		x	x		
	TNX				x				x		x	x		
	TXX				x				x		x	x		
	TXN				x				x		x	x		
	ID				x				x		x	x		
	FD				x				x		x	x		
	SU				x				x		x	x		
Heat wave	TR				x				x		x	x		
	WSDI	x			x				x		x	x		
Drought	CDD	x						x			x			
	SPI3	x						x			x			
Mountains climate hazard	PRCPTOT		x		x								x	
	TG		x		x								x	
	FD		x		x								x	
Orchard system	GSL								x					
	HW								x					
	PRCPTOT								x					
	RX1DAY								x					
	RX5DAY								x					
	SDII								x					
	R10								x					
	R20								x					
	CDD								x					
	SU								x					
	TR								x					
	TXX								x					



**Table A2**

Description of the climate hazards tailored indicators for each project.

Indicators	Description
CDD Consecutive Dry Days(days)	Largest number of consecutive days with daily precipitation less than 1 mm.
WD Warm-dry days (days)	Number of days with daily mean temperature greater than 75th percentile of daily mean temperature and with daily precipitation less than 75th percentile of daily precipitation.
PRCPTOT Accumulated Precipitation in wet days(mm)	Daily precipitation sum in wet days (days with precipitation greater than or equal to 1 mm).
RX1DAY Maximum 1-day precipitation (mm/day)	Maximum 1-day precipitation amount.
RX5DAY Maximum 5-days precipitation (mm/days)	Maximum consecutive 5-day precipitation amount.
SDII Daily precipitation (mm/day)	Simple precipitation intensity index.
R10-Heavy precipitation days (days)	Number of days with daily precipitation greater than or equal to 10 mm.
R20-Very heavy precipitation days (days)	Number of days with daily precipitation greater than or equal to 20 mm.
TR10pr- 10-year return period (precipitation) (mm)	10-year return period for the daily precipitation.
TR100pr- 100-year return period (precipitation) (mm)	100-year return period for the daily precipitation.
RR1-Wet Days(days)	Number of days with precipitation greater than or equal to 1 mm.
TNN-Minimum of minimum temperature(°C)	Minimum value of daily minimum temperature.
TNX-Maximum of minimum temperature(°C)	Maximum value of daily minimum temperature.
TXN-Minimum of maximum temperature (°C)	Minimum value of daily maximum temperature.
TXX-Maximum of maximum temperature (°C)	Maximum value of daily maximum temperature.
ID-Ice Days (days)	Number of days with daily maximum temperature less than 0 °C.
FD-Frost Days (days)	Number of days with daily minimum temperature less than 0 °C.
SU-Summer Days (days)	Number of days with daily maximum temperature greater than 25 °C.
TR-Tropical Nights (days)	Number of days with daily minimum temperature greater than 20 °C.
WSDI-Warm Spell Duration Index (days)	Total number of days per period (annual or seasonal) in which the daily maximum temperature is greater than the 90th percentile* of the daily maximum temperature in intervals of at least 6 consecutive days.
CDD Consecutive Dry Days(days)	Largest number of consecutive days with daily precipitation less than 1 mm.
SPI3- Standard precipitation index 3 MONTHS (%)	The percentage of classes occurrence (Extremely wet, Very wet, Moderately wet, Normal, Near Normal, Moderately drought, Severe drought, Extremely drought) in SPI3 index (Standard precipitation index computed for shorter accumulation period: 3 months).
TG	Mean of daily mean temperature.
GSL-Growing Season Length (days)	Number of days between the first occurrence of at last six consecutive days with daily mean temperature greater than 5 °C and the first occurrence after 1st July (NH) or 1st January (SH) of at least six consecutive days with daily mean temperature less than 5 °C.
HW-Hot Waves (days)	Number of days with daily maximum temperature greater than 35 °C.
TXX-Maximum of maximum temperature (°C)	Maximum value of daily maximum temperature.

droughts, geo-hydrological risks and floodings, increase in temperatures, climate hazards in mountain areas, and climate hazards related to the fruit and the agricultural systems (as reported in Table 3). In addition, the information collected from the first phase of CMCC has been useful to define the exposure sample to the relative climate hazards. The exposure samples (inserted in Table 3) are strictly related to the impacts perception highlighted by local stakeholders.

**Table B1**

Climate adaptation solutions identified in trans-regional Climate Adaptation Planning process for local development projects in small municipalities methodology.

N°	Proposing entity	Climate Change adaptation measures
1	Amici dei Sentieri	GREEN - Forestry, - Rehabilitation of the soil, damaged by landslides, by earthmoving means, to construct retaining walls, where necessary, and to restore the course of the stream, - Maintenance work on the lake basin
2	Associazione Pourparler	SOFT - Automatic water level and precipitation monitoring system, SOFT - Development of the Charter of Values (expression of local knowledge) and good practices in combating climate change, Creation of a network of academic institutions, integrated supply chains, institutional and cultural actors.
3	Municipality of Acqui Terme	GREEN- Development of green areas giving particular attention to native tree species that have greater removal capacity of gaseous pollutants (O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> ) and carbon dioxide (CO <sub>2</sub> ), - Construction of social gardens and green areas for social and recreational activities with differentiated management of meadows and soils for the enhancement of biodiversity. SOFT - Information and communication actions to citizens to ensure that their valuable services and benefits are understood.
4	Municipality of Alagna Valsesia	GREY- Rehabilitation and upgrading of the pylon and the arrival station of the Punta Indren cable car (Gressoney LT, AO) with high environmental performance.
5	Municipality of Almese*	GREEN/GREY Development of Nature Based Solutions in the built environment.
6	Municipality of Avigliana	GREY - a "Caselette bealera" discharger upstream of the Grangia hamlet and the restoration of the irrigation canal network in the Drubiaglio hamlet. - Facilitate irrigation of agricultural fields in the Drubiaglio area through new channels. - Implementation of any other micro-measures to reduce surface runoff.
7	Municipality of Cavour*	SOFT - Raising awareness of water saving issues among citizens. SOFT Launch of a local process of knowledge and operation on the issues of climate change, with the aim of developing the resilience of the territorial fruit system in the medium-long term.
8	Municipality of San Lazzaro Sesia	SOFT - Information and training of the population on climate change, - Involvement of the population of the partner municipalities in the collection of data on extreme climatic events in the last 30 years, - Participatory definition of mitigation and adaptation actions to be implemented.
9	Municipality of Viarigi	SOFT Found a Land Association (henceforth ASFO) that will be the subject responsible for the management of these lands. GREEN/GREY Development of Nature Based Solutions in the built environment.
10	Province of Savona	SOFT - Information and training of the population on climate change, - Involvement of the population of the partner

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**Table B1 (continued)**

N°	Proposing entity	Climate Change adaptation measures
		municipalities in the collection of data on extreme climatic events in the last 30 years, - Participatory definition of mitigation and adaptation actions to be implemented, - Improvement of alarm procedures in case of extreme weather events- Communication and involvement of other actors in the surrounding area (with educational tourism) for the dissemination of what has been achieved and learned. GREY Increase of forestry areas and ecological corridors, Increase the amount of green areas in the built environment.
11	Società Meteorologica Italiana Onlus	SOFT Implementing practices to create awareness and resilience on climate change in the Alpine environment: - Information to citizens on climate change and sustainable architectural recovery with meetings and conferences also for tourist audiences; - Information totem on climate change at the shopping center and tourist office; bulletin board on the state of the climate in the Vazon village; - Climate change exhibition at the former school in Vazon; - Oulx High School and Vazon University Summer Schools;- Planning of second homes and rehabilitation of mountain hamlets as a response to global warming (managed retreat) ; - Forest fire risk awareness in relation to future climate scenarios; GREY/GREEN - Maintenance of the territory to increase resilience to intense rainfall events: restoration of dry stone walls to protect local roads; paving and drainage village subject to erosion during storms.- Water storage for irrigation of horticultural crops (potatoes, cabbages) intended for the local short chain in anticipation of more frequent droughts;
12	Tanaro Valley Mountain Union	SOFT Citizens training to become environmental Sentinels, and to play an active role during emergencies. GREY Implementation by local companies of land management actions aimed at the prevention of geo-hydrological instability.

**4.3. Improvement of a performed high-resolution climate analyses**

As next step, the local climate profile analysis has been performed based on the adaptation goal of the twelve pilot projects involved in the test case of the Call “Mutamenti” and the sector involved. In most of the pilot projects, geo-hydrological instability is identified as a potential risk. From the climate analysis, obtained by the ensemble mean of the regional climate models at the highest resolution included in the EURO-CORDEX program, it emerges that it is expected a general increase in the maximum values of daily precipitation for the different areas and in a more evident way for the 2050 s period in RCP8.5 scenario. However, it should be borne in mind that the precipitation signal and the indicators that depend on this variable are affected by an important uncertainty, in particular for mountainous areas.

As regards the impacts of climate change on the fire regime, it shows a statistically significant increase in the fire triggering condition, much more marked for the RCP8.5 scenario from 2070 onwards. For winter tourism, climate hazards that have been analyzed are increased temperatures and reduced precipitation (especially in the winter season)

**Table B2**

Detailed questions submitted by CMCC for each project stakeholder partner to achieve information and data able to quantify from quantitative and qualitative point of view the exposure sample and vulnerability of the system.

N°	Proposing entity	Exposed sample	Vulnerability
1	Amici dei Sentieri	<b>FOREST</b> How many foresters are there in the municipality? How much is the forest area used for production and protection at municipal level? What are the tree and herbaceous species that the municipality wants to protect?  <b>LAKE</b> What additional elements of exposure can there be in relation to the sample removed from the lake? Is there a plumbing system that feeds the contents of the lake?	<b>FOREST</b> Which are the most degraded plant species? Which plants have the greatest benefit within the local forest? What, in your opinion, are the plants to give priority to their reintroduction into the forests? Is there on the territory an area planned by Piani Forestali Aziendali with management guidelines for adaptation? Is it possible to quantify the percentage change in land consumption in recent years? <b>LAKE</b> What is the degree of maintenance of the shores of the lake? If the shores of the lake are waterproofed, is maintenance carried out on these surfaces? Is the lake’s range monitored?
2	Associazione Pourparler	<b>SMALL VILLAGE</b> Which population target is most exposed?What are the most exposed elements within the territory (e.g. residential centers, shopping centers, hospitals, other) ? Which is the level of risk perception in the territory? What are the possible solutions to increase the perception of risk at the municipal level? <b>TOURISM</b> Are there tourist information offices? What is the percentage of tourist accommodation in the area? If present, are these activities mainly aimed at winter tourism or summer tourism? Are there Alpine structures or installations with high landscape value? Do the activities of accommodation establishments seem to have decreased with time?  <b>WINTER TOURISM</b> Are there winter sports centres? Is there any infrastructure for winter tourism?  <b>SUMMER TOURISM</b> Are there any hiking	<b>SMALL VILLAGE</b> What are the main problems that are encountered within your urban/ mountain settlement? What are the characteristics that make the territorial system more at risk? Are there any awareness-raising campaigns to broaden knowledge about climate change in mountain areas?Are there ad hoc warning systems to alert the population (especially the vulnerable) to the occurrence of a certain climate danger (e.g. hydro-geological risk, heat waves, cold waves, etc.) ? The percentage of the population over 65 is: high, medium, low? The percentage of population over 85 is: high, medium, low? Is the percentage of population under 6 years old: high, medium, low?  <b>WINTER TOURISM/ SUMMER TOURISM</b> Can you indicate the percentage ratio between the number of residents and the number of tourist arrivals during the year? If

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Table B2 (continued)

N°	Proposing entity	Exposed sample	Vulnerability
		trails?If present, what/ who are they aimed at (e.g. cyclists, hickings, other) ? Is there any infrastructure for summer tourism?	YES, how much (in %) ? Do businesses seem to adapt to the new needs of tourists? Do you find a level of flexibility: high, medium or low? Is there adequate resource management in times of "boom" tourism? Are there activities on the territory to satisfy different cultural interests/ entertainment/ entertainment for the public? Is there a high degree of openness to sustainability issues on the part of the administrations present? Are there procedures and/ or plans for the management of natural hazards within the villages and during periods of increasing tourist flows?
3	Municipality of Acqui Terme	POPULATION How many people have been affected by the recent floods? Who, in your opinion, are the most fragile subjects?  BUILT ENVIRONMENT What is the percentage of residential areas? What is the percentage of commercial areas? What is the percentage of industrial areas? What percentage of designated areas use historic environmental assets? What is the percentage of target areas for cultural use? Have there been floods that have caused damage to the built environment? If YES, which buildings were most affected? Are there areas where the built environment is more at risk than others?  INFRASTRUCTURES Are there roads in places/ environments that could be adversely affected by flooding or landslides? Are there any railways in places/environments that could be adversely affected by flooding or landslides? Are there bike paths in places/environments that could be adversely affected by flooding or landslides? Are there energy production infrastructures in places/environments	POPULATION The percentage of the population over 65 is: high, medium, low? The percentage of population over 85 is: high, medium, low? Is the percentage of population under 6 years old: high, medium, low? Are there any awareness-raising campaigns to broaden knowledge about climate change?Are there ad hoc warning systems to alert the population (especially the vulnerable) to the occurrence of a certain climate danger (e. g. hydro-geological risk, heat waves, cold waves, etc.) ?  BUILT ENVIRONMENT What is the incidence of poorly preserved buildings? Has there been a reduction in green areas? What are the main problems that are encountered within your built environment? What are the characteristics that make the territorial system more at risk? Is there the presence of hydraulic works? Was there an opening on the issues of sustainability and/or climate change? Has the Master Plan been updated with respect to the indications of the PAI and the Basin Plan?

Table B2 (continued)

N°	Proposing entity	Exposed sample	Vulnerability
		that could be adversely affected by the occurrence of floods or landslides?	INFRASTRUCTURES Are there bridges and viaducts in the area? What could be - in your opinion - the percentage ratio between the population moving daily for work/study purposes using their own motor? What could be - in your opinion - the percentage ratio between the population moving daily for work/study purposes using collective means of transport (e.g. train, bus, etc.) ? What could be - in your opinion - the percentage ratio between the population that moves daily for work/study purposes using the bike or walking? Are there more critical infrastructures than others? Has there been an opening on the issues of sustainability and/or climate change in relation to the infrastructure system?
4	Municipality of Alagna Valsesia	TOURISM Are there tourist information offices? What is the percentage of tourist accommodation in the area? If present, are these activities mainly aimed at winter tourism or summer tourism? Are there Alpine structures or installations with high landscape value? Do the activities of accommodation establishments seem to have decreased with time?  WINTER TOURISM Are there winter sports centres? Is there any infrastructure for winter tourism?  SUMMER TOURISM Are there any hiking trails?If present, what/ who are they aimed at (e.g. cyclists, hickings, other) ? Is there any infrastructure for summer tourism?	WINTER TOURISM/ SUMMER TOURISMCan you indicate the percentage ratio between the number of residents and the number of tourist arrivals during the year? If YES, how much (in %) ? Do businesses seem to adapt to the new needs of tourists? Do you find a level of flexibility: high, medium or low? Is there adequate resource management in times of "boom" tourism? Are there activities on the territory to satisfy different cultural interests/ entertainment/ entertainment for the public? Is there a high degree of openness to sustainability issues on the part of the administrations present? Are there procedures and/ or plans for the management of natural hazards within the villages and during periods of increasing tourist flows?  OTHER Are there any research institutes in the area to study climate change? If YES, what do they deal with specifically?

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Table B2 (continued)

N°	Proposing entity	Exposed sample	Vulnerability
			If YES, would you be in favor of creating medium/ long term partnerships?
5	Municipality of Almese*	<p><b>POPULATION</b> How many people have been affected by the recent floods? Who, in your opinion, are the most fragile subjects?</p> <p><b>BUILT ENVIRONMENT</b> What is the percentage of residential areas? What is the percentage of commercial areas? What is the percentage of industrial areas? What percentage of designated areas use historic environmental assets? What is the percentage of target areas for cultural use? Have there been floods that have caused damage to the built environment? If YES, which buildings were most affected? Are there areas where the built environment is more at risk than others?</p> <p><b>INFRASTRUCTURES</b> Are there roads in places/ environments that could be adversely affected by flooding or landslides? Are there any railways in places/environments that could be adversely affected by flooding or landslides? Are there bike paths in places/environments that could be adversely affected by flooding or landslides? Are there energy production infrastructures in places/environments that could be adversely affected by the occurrence of floods or landslides?</p>	<p><b>POPULATION</b> The percentage of the population over 65 is: high, medium, low? The percentage of population over 85 is: high, medium, low? Is the percentage of population under 6 years old: high, medium, low? Are there any awareness-raising campaigns to broaden knowledge about climate change? Are there ad hoc warning systems to alert the population (especially the vulnerable) to the occurrence of a certain climate danger (e. g. hydro-geological risk, heat waves, cold waves, etc.) ?</p> <p><b>BUILT ENVIRONMENT</b> What is the incidence of poorly preserved buildings? Has there been a reduction in green areas? What are the main problems that are encountered within your built environment? What are the characteristics that make the territorial system more at risk? Is there the presence of hydraulic works? Was there an opening on the issues of sustainability and/or climate change? Has the Master Plan been updated with respect to the indications of the PAI and the Basin Plan?</p> <p><b>INFRASTRUCTURES</b> Are there bridges and viaducts in the area? What could be - in your opinion - the percentage ratio between the population moving daily for work/study purposes using their own motor? What could be - in your opinion - the percentage ratio between the population moving daily for work/study purposes using collective means of transport (e.g. train, bus, etc.)? What could be - in your opinion - the percentage ratio between the population that moves daily for work/study purposes using the bike or</p>

Table B2 (continued)

N°	Proposing entity	Exposed sample	Vulnerability
			walking? Are there more critical infrastructures than others? Has there been an opening on the issues of sustainability and/or climate change in relation to the infrastructure system?
6	Municipality of Avigliana	<p><b>POPULATION</b> Which population target is most exposed? What are the most exposed elements within the territory (e.g. residential centers, shopping centers, hospitals, other)? How many inhabitants are affected (in terms of health) by the impacts of climate change? How many inhabitants are affected (in economic terms) by the impacts of climate change? How many inhabitants are affected (in social terms) by the impacts of climate change? How, in your opinion, are the most fragile subjects?</p> <p><b>AGRICULTURAL</b> What are the most common crops on the territory? Is there an indication of the utilized agricultural area and the area under arboriculture? How much municipal area (ha) is used in agricultural areas in the municipal territory [Sistema Piemonte - Anagrafe Agricola Unica]? How much is the area predominantly pastoral (e. g., bushes, grasslands, pastures, etc.) resident in the municipal territory? Are there any farms in the municipality [Sistema Piemonte - Anagrafe Agricola Unica]? Are there farms in the municipality [Sistema Piemonte - Anagrafe Agricola Unica]? And which farms are most affected by the impacts of climate change? Is there a number of people who are employed in agriculture and forestry?</p> <p><b>AGRICULTURAL AND FRUIT SYSTEM</b> What are the main species of orchards on the territory? Is there a variety of species, or is there just one</p>	<p>POPULATION The percentage of the population over 65 is: high, medium, low? The percentage of population over 85 is: high, medium, low? Is the percentage of population under 6 years old: high, medium, low? Are there any awareness-raising campaigns to broaden knowledge about climate change? Are there ad hoc warning systems to alert the population (especially the vulnerable) to the occurrence of a certain climate danger (e.g. hydro-geological risk, heat waves, cold waves, etc.)?</p> <p><b>AGRICULTURAL</b> In relation to the agricultural sector, a large part of the land is used for: maize cultivation, permanent grassland, orchards, pasture. Are there springs with water catchment for irrigation in the municipality? Are there any farms with farmers over 65? Is this the municipality with a Civil Protection Plan? To the best of your knowledge, do most farms have active insurance policies available as collateral in the event of extreme events? Is there a direct link between agricultural workers and local authorities? Are any adaptation measures in place to prevent damage to the agricultural system? Has there been any variation in pathogen attacks (species and frequency)?</p> <p><b>AGRICULTURAL AND FRUIT SYSTEM</b> What is the density of a plantation? (roughly) What is the level of hydraulic conductivity of soils?</p>
7	Municipality of Cavour*		

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Table B2 (continued)

N°	Proposing entity	Exposed sample	Vulnerability
		kind of orchard? How many fruit companies are present in the territory?	Is sustainable management of the entire system active? Is there an emergency secondary water distribution system available? Are any adaptation measures in place to prevent damage to the fruit sector? If so, what measures? Are there springs or springs with water catchment for irrigation in the municipality? Are there any fruit companies with holders over 65? Does the municipality have a Civil Protection Plan? If YES, which one? To the best of your knowledge, do most fruit and vegetable companies have active insurance policies available as collateral in the event of extreme events? Is there a direct channel between those employed in the fruit sector and the local authorities? Are adaptation measures in place to prevent damage to the fruit system? If so, what measures? Which of these phenomena were made present: advance of the date of flowering, shortening of the growth period and consequent early ripening of the fruits (especially in the most southern), reduction in the size of the fruits? Has there been an increase in irrigation requests? There has been a shortage of water during specific stages of development such as flowering, pollination and filling of the fruit? Has there been any variation in pathogen attacks (species and frequency)?
8	Municipality of San Lazzaro Sesia	AGRICULTURAL SYSTEM - RICE SECTOR What are the most common rice crops on the territory? Is there an indication of the agricultural area used for the cultivation of rice? How much municipal area (ha) is the agricultural area used for the cultivation of rice [Sistema Piemonte - Anagrafe Agricola Unica]? Are there farms for rice cultivation	AGRICULTURAL SYSTEM - RICE SECTOR Are there springs or springs with water catchment for irrigation in the municipality? Are there any rice-growing farms with farmers over the age of 65? Does the municipality have a Civil Protection Plan? If YES, which one? To the best of your knowledge, do most rice farms have active

Table B2 (continued)

N°	Proposing entity	Exposed sample	Vulnerability
		in the municipality [Sistema Piemonte - Anagrafe Agricola Unica]? If YES, what companies are they (mostly)? ? Among these, which farms are most affected by the impacts of climate change? Are there a number of people who are employed in the agricultural sector for the cultivation of rice? The income from the tourist flows for the cultivation of rice is: significant, irrelevant. What is the percentage of tourist accommodation in the area?	insurance policies available to them as a guarantee in the event of extreme events? Is there a direct channel between those employed in the agricultural sector of rice cultivation and the local authorities? Adaptation measures are in place to prevent damage to the agricultural rice sector? If so, what? Has there been any variation in pathogen attacks (species and frequency)? The stress caused by high temperatures damages the quality of rice? If so, which one? Has there been a change in the quality of production? Is there an alert system to deal with "seasonal unpredictability"? If Yes, what kind? Is there a strategy to optimize water management?
9	Municipality of Viarigi	BUILT ENVIRONMENT What is the percentage of residential areas? What is the percentage of commercial areas? What is the percentage of industrial areas? What percentage of designated areas use historic environmental assets? What is the percentage of target areas for cultural use? Have there been floods that have caused damage to the built environment? If YES, which buildings were most affected? Are there areas where the built environment is more at risk than others?  WINE SECTOR What is the percentage of wine-growing areas? What is the percentage of operators in the wine sector? What are the main species of vines on the territory? The income deriving from the tourist/eno-gastronomic flows are: significant, irrelevant. What is the percentage of tourist accommodation in the area?	BUILT ENVIRONMENT What is the incidence of poorly preserved buildings? Has there been a reduction in ecosystem services (reduction of biodiversity, reduction of usable spaces for man for productive and recreational use)? What are the main problems encountered within the built environment? (percentage of waterproofed areas, presence of floodable underpasses, natural orographic conformation) Is there a depopulation of the municipality in recent years? What are the characteristics that increase the level of risk of your territorial system? Is there the presence of hydraulic works? What is the level of maintenance of open spaces in the built environment and in rural areas? Are there abandoned rural and wooded areas? Have you noticed an increase in the events of geo-hydrological instability in the built environment as a result of the abandonment of rural areas? Are there economic activities that can be settled that could potentially increase the maintenance of the

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Table B2 (continued)

N°	Proposing entity	Exposed sample	Vulnerability
			territory (viticulture, truffle, terraces, managed forest) ? Was there an opening on the issues of sustainability and/or climate change? Has the Master Plan been updated in accordance with the PAI and the Master Plan?
			WINE SECTOR The stress caused by high temperatures damages the quality of the buds and alters their growth and production? If so, which of these? Has there been any variation in pathogen attacks (species and frequency) ? There is an alert system to deal with "seasonal unpredictability"? If Yes, what kind? Is there a strategy aimed at optimizing the management of water resources, both in the processing of the cellar and in the treatments in the vineyard? Have techniques been applied to plant vines at high altitudes and move them into shady areas?
10	Province of Savona	FOREST How many foresters are there in the municipality? How much is the forest area used for production and protection at municipal level? What are the tree and herbaceous species that the municipality wants to protect?  TOURISM Are there tourist information offices? What is the percentage of tourist accommodation in the area? If present, are these activities mainly aimed at winter tourism or summer tourism? Are there Alpine structures or installations with high landscape value? Do the activities of accommodation establishments seem to have decreased with time?  WINTER TOURISM Are there winter sports centres? Is there any infrastructure for winter tourism?	FOREST Which are the most degraded plant species? Which plants have the greatest benefit within the local forest? What, in your opinion, are the plants to give priority to their reintroduction into the forests? Is there on the territory an area planned by Piani Forestali Aziendali with management guidelines for adaptation? Is it possible to quantify the percentage change in land consumption in recent years? WINTER TOURISM/ SUMMER TOURISM Can you indicate the percentage ratio between the number of residents and the number of tourist arrivals during the year? If YES, how much (in %) ? Do businesses seem to adapt to the new needs of tourists? Do you find a level of flexibility: high, medium or low? Is there adequate resource management in times of

Table B2 (continued)

N°	Proposing entity	Exposed sample	Vulnerability
		SUMMER TOURISM Are there any hiking trails? If present, what/ who are they aimed at (e.g. cyclists, hickings, other) ? Is there any infrastructure for summer tourism?	"boom" tourism? Are there activities on the territory to satisfy different cultural interests/ entertainment/ entertainment for the public? Is there a high degree of openness to sustainability issues on the part of the administrations present? Are there procedures and/or plans for the management of natural hazards within the villages and during periods of increasing tourist flows?
11	Società Meteorologica Italiana Onlus	SMALL VILLAGE Which population target is most exposed? What are the most exposed elements within the territory (e.g. residential centers, shopping centers, hospitals, other)? Which is the level of risk perception in the territory? What are the possible solutions to increase the perception of risk at the municipal level? TOURISM Are there tourist information offices? What is the percentage of tourist accommodation in the area? If present, are these activities mainly aimed at winter tourism or summer tourism? Are there Alpine structures or installations with high landscape value? Do the activities of accommodation establishments seem to have decreased with time?  WINTER TOURISM Are there winter sports centres? Is there any infrastructure for winter tourism?  SUMMER TOURISM Are there any hiking trails? If present, what/ who are they aimed at (e.g. cyclists, hickings, other) ? Is there any infrastructure for summer tourism?  AGRICULTURAL What are the most common crops on the territory? Is there an indication of the utilized agricultural area and the area under arboriculture? How much municipal area (ha) is used in agricultural	SMALL VILLAGE What are the main problems that are encountered within your urban/ mountain settlement? What are the characteristics that make the territorial system more at risk? Are there any awareness-raising campaigns to broaden knowledge about climate change in mountain areas? Are there ad hoc warning systems to alert the population (especially the vulnerable) to the occurrence of a certain climate danger (e.g. hydro-geological risk, heat waves, cold waves, etc.) ? The percentage of the population over 65 is: high, medium, low? The percentage of population over 85 is: high, medium, low? Is the percentage of population under 6 years old: high, medium, low?  WINTER TOURISM/ SUMMER TOURISM Can you indicate the percentage ratio between the number of residents and the number of tourist arrivals during the year? If YES, how much (in %) ? Do businesses seem to adapt to the new needs of tourists? Do you find a level of flexibility: high, medium or low? Is there adequate resource management in times of "boom" tourism? Are there activities on the territory to satisfy different cultural interests/ entertainment/ entertainment for the

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Table B2 (continued)

N°	Proposing entity	Exposed sample	Vulnerability
		<p>areas in the municipal territory [Sistema Piemonte - Anagrafe Agricola Unica]?How much is the area predominantly pastoral (e.g., bushes, grasslands, pastures, etc.)</p> <p>resident in the municipal territory?</p> <p>Are there any farms in the municipality [Sistema Piemonte - Anagrafe Agricola Unica]?</p> <p>Are there farms in the municipality [Sistema Piemonte - Anagrafe Agricola Unica]?</p> <p>And which farms are most affected by the impacts of climate change?</p> <p>Is there a number of people who are employed in agriculture and forestry?</p>	<p>public?</p> <p>Is there a high degree of openness to sustainability issues on the part of the administrations present?</p> <p>Are there procedures and/or plans for the management of natural hazards within the villages and during periods of increasing tourist flows?</p> <p>AGRICULTURAL</p> <p>In relation to the agricultural sector, a large part of the land is used for: maize cultivation, permanent grassland, orchards, pasture.</p> <p>Are there springs with water catchment for irrigation in the municipality?</p> <p>Are there any farms with farmers over 65?</p> <p>Is this the municipality with a Civil Protection Plan?</p> <p>To the best of your knowledge, do most farms have active insurance policies available as collateral in the event of extreme events?</p> <p>Is there a direct link between agricultural workers and local authorities?</p> <p>Are any adaptation measures in place to prevent damage to the agricultural system?Has there been any variation in pathogen attacks (species and frequency)</p> <p>?</p>
12	Tanaro Valley Mountain Union	<p>POPULATION</p> <p>How many people have been affected by the recent floods?</p> <p>Who, in your opinion, are the most fragile subjects?</p> <p>BUILT ENVIRONMENT</p> <p>What is the percentage of residential areas?</p> <p>What is the percentage of commercial areas?</p> <p>What is the percentage of industrial areas?</p> <p>What percentage of designated areas use historic environmental assets?</p> <p>What is the percentage of target areas for cultural use?</p> <p>Have there been floods that have caused damage to the built environment?</p> <p>If YES, which buildings were most affected? Are there areas where the built environment is more at</p>	<p>POPULATION</p> <p>The percentage of the population over 65 is: high, medium, low?</p> <p>The percentage of population over 85 is: high, medium, low?</p> <p>Is the percentage of population under 6 years old: high, medium, low?</p> <p>Are there any awareness-raising campaigns to broaden knowledge about climate change?Are there ad hoc warning systems to alert the population (especially the vulnerable) to the occurrence of a certain climate danger (e.g. hydro-geological risk, heat waves, cold waves, etc.)</p> <p>?</p> <p>BUILT ENVIRONMENT</p> <p>What is the incidence of poorly preserved buildings?</p>

Table B2 (continued)

N°	Proposing entity	Exposed sample	Vulnerability
		<p>risk than others?</p> <p>INFRASTRUCTURES</p> <p>Are there roads in places/environments that could be adversely affected by flooding or landslides?</p> <p>Are there any railways in places/environments that could be adversely affected by flooding or landslides?</p> <p>Are there bike paths in places/environments that could be adversely affected by flooding or landslides?</p> <p>Are there energy production infrastructures in places/environments that could be adversely affected by the occurrence of floods or landslides?</p>	<p>Has there been a reduction in green areas?</p> <p>What are the main problems that are encountered within your built environment?</p> <p>What are the characteristics that make the territorial system more at risk?</p> <p>Is there the presence of hydraulic works?</p> <p>Was there an opening on the issues of sustainability and/or climate change?</p> <p>Has the Master Plan been updated with respect to the indications of the PAI and the Basin Plan?</p> <p>INFRASTRUCTURES</p> <p>Are there bridges and viaducts in the area?</p> <p>What could be - in your opinion - the percentage ratio between the population moving daily for work/study purposes using their own motor?</p> <p>What could be - in your opinion - the percentage ratio between the population moving daily for work/study purposes using collective means of transport (e.g. train, bus, etc.)</p> <p>?</p> <p>What could be - in your opinion - the percentage ratio between the population that moves daily for work/study purposes using the bike or walking?</p> <p>Are there more critical infrastructures than others?</p> <p>Has there been an opening on the issues of sustainability and/or climate change in relation to the infrastructure system?</p>

while for the orchard system different climatic hazards have been considered such as: heat waves, frost days in spring season, extreme events of precipitation that can damage the crop and drought.

After the high-resolution climate analysis, the results have been shared through a Dataclimate platform. Dataclimate is a climate service (<https://www.dataclimate.com>) developed by REgional Models and geo-Hydrological Impacts Division (REMHI) of CMCC. Conceived as a web-based and multi-product tool, Dataclimate takes care of the whole information production chain: from the climate data collection/storage until the processing phase of climate data, according to the user's needs.

Fig. 5 shows the process developed in the trans-regional Climate Adaptation Planning process for local development projects in small municipalities methodology for climate hazard analysis and for sharing information through the platform.

The use of this platform is very relevant to the project, permitting an easy access and consultation of the climate information by all the

stakeholders. Specifically the end-users can visualize and download different types of data (maps, chart, table data, shapefile) that can be easily integrated with other data platforms. In addition, it also represents the opportunity to easily reach climate experts requiring additional details and information on the climate data provided.

#### 4.4. Increase the awareness of the impacts of climate change on proposing entities territories and prepare the ground for the implementation of pilot projects

The results of the local climate profiles have been presented in another round of public meetings engaging each proposing entity by CMCC. These results could be useful in the future for the small municipalities to support the development of policies and projects related to climate change.

In those meetings with the pilot project proposing entities, CMCC had described the exposure samples, in order to define the perimeters of the risk assessment and to identify coherent possible adaptation solutions. This phase was also crucial in preparing the pilot project's entities and stakeholders (i.e. public administrations, the third sector, the private sector and local institutions) to submit the completed questionnaires to CMCC; this was intended to collect information and data useful for identifying the current conditions in terms of vulnerability through susceptibility and adaptive capacity of local communities.

To support the final design pilot projects implementation phase, the different proposed climate change adaptation measures identified by each pilot project were categorized by CMCC in three classes: green, grey, and soft adaptation measures (see [Table B1](#) in Appendix B). This classification follows the guidelines for "Green City" elaborated by Green City Network (FSS, 2018; SGGE, 2017) and shooting from Tucci et al. [32].

#### 4.5. Development of ad-hoc questionnaires for stakeholder engagement

The development of exposure and vulnerability assessment questionnaires was the strategy to collect more qualitative and quantitative information in a short time period and through the support of local communities. Questions have been formulated based on the exposure sample identified for each of the 12 winning pilot project proposals in the perspective, not only to collect data and information from the vulnerability point of view of each system, but also to deepen the knowledge related to the exposure samples. The structure described the physical, social and institutional dimensions of the exposure and of the vulnerability for each system. At the same time, questions oriented to collect information related to awareness to climate topics at institutional levels, presence of building codes that underpins climate change indications and availability of early warning systems are key aspects to understand the level of adaptive capacity of local communities to the effects of climate change [29,30,33–36]. The questions were submitted by CMCC for each proposing entity requiring the response of a minimum of 5 stakeholders involved and/or related to the projects. It has been given a week to replace with the answers. [Table B2](#) in the Appendix B shows the structured question by project, divided by exposed sample and vulnerability (i.e., sensitivity and adaptive capacity).

#### 4.6. Definition of qualitative risk assessment results and mainstreaming of adaptation measures proposed in the pilot project development phase

The last step of the proposed methodology in the test of Call "Mutamenti" consisted in the production of the 12 reports based on the results obtained within each step. Therefore, the main contents of the reports were:

- the description of project goals in the short, medium and long period;
- the description of local climate profile and the results of the calculation of selected indicators for climate hazards;

- the description of the answers received for the questions related for each exposure sample;
- the description of the information received for vulnerability inherent to each exposure sample;
- the main critical factors in terms of vulnerability highlighted as a focus for future local development policies where the Public Administration need to focus on;
- the description of the guidelines to develop (in the next future) a quantitative risk assessment based on the IPCC principles, thanks to the availability of past and future climate time series provided by CMCC.

This report supported the pilot project development of each proposing entity and the implementation of the local climate adaptation measures in a more detailed design version for the next phase. In addition could support in the future the work of small municipalities when they would undertake initiatives related to climate change adaptation.

## 5. Discussion

Due to the increasing impacts of climate change at the local scale, adaptation has gained a crucial role to increase the level of resilience of different systems such as the built environment, infrastructural systems, natural environment, agricultural systems, population and others. Climate adaptation process is playing an important role also in the policies and planning debates, characterized by the engagement of civil society, third parties and the private sector [18].

According to the research question, the Climate Change Adaptation cycle for pilot projects development in small municipalities was idealized, conceptualized and developed in order to define an operational process to support the decision and design making of small municipalities and the other partners involved in the design of pilot climate adaptation measures.

The gaps of small municipalities in pilot project development for climate change adaptation identified through the literature review were overcome through a coherent and clear process, the transfer of internationally approved methodologies and techniques for climate adaptation and risk assessment and by the continuous support of CSP and CMCC as founding partner and scientific committee. Climate Change Adaptation cycle for pilot projects development in small municipalities built adapted to the pilot projects proposal characteristics and by a common knowledge ground related to international framework for climate change adaptation and on local climate specific conditions permit to adjust the proposed pilot adaptation measures, and to increase the mainstreaming level of adaptation practices within local communities through a bottom up stakeholder engagement. The Climate Change Adaptation cycle for pilot projects development in small municipalities methodology involved in the test case Call "Mutamenti" has therefore been the activator of partnerships among different local actors in line with the goal of each project that can support the territorial and local transformation, especially in small and marginalized communities, integrating and unifying the different actors' needs and increasing the multiple benefits at the local scale. In addition, the contribution of the proposed methodology to the consolidated methods for climate change adaptation actions underline that framework proposed at international level such as UNFCCC, can be applied in small contexts without plans and policies for adaptation. Adoption of high resolution climate hazard assessment in the risk analysis process could enrich the quality of the methodology proposed in LIFE LOCAL ADAPT research project (2021). Trying to avoid mal-adaptation initiatives, the engagement of local authorities and partners of the pilot projects in the entire process of project assessment in the framework of climate change adaptation could be considered as an innovative practice that could be mainstreamed in the future in local administration procedures.

The Climate Change Adaptation cycle for pilot projects development



in small municipalities methodology was able to cover the lack reported in the 1) Introduction, filling the gaps of local entities in terms of scarce information and knowledge related to climate change in small municipalities, identification of local threats due to climate change, scarce financial resources to design and implement demonstrative pilot projects for climate change adaptation, giving:

- an increasing of information related to climate change impacts observed and future climate change impacts expected through climate change projections developed for each territorial entities;
- Compagnia di San Paolo Foundation erogate adequate financial resources to support the detailed design phase conducted by each pilot project proposing entities ensuring this through the support of scientific committee such as CMCC that transfer the international knowledge and techniques adopted to climate change adaptation cycle;
- an increasing of knowledge, in terms of technical skills and awareness related to climate change adaptation, of the stakeholder that participate in the process such as Public Administration, third sector, private companies;
- a smart and easy methodology such as Climate Change Adaptation cycle s for pilot projects development in small municipalities to ensure an adequate process also with less time availability giving useful information to raise awareness, the bodies proposing the projects, and deepen in the future.

To implement this methodology, a territorially varied and small-town environment was particularly suitable for validating the process. Small municipalities often do not have the key tools to face the impacts of climate change even if they have a high perception on which are the local vulnerabilities and the main critical and relevant issues.

In addition to the method proposed by Litt et al. [18], From the very beginning of the case study test Call for proposals, there was an active involvement of stakeholders and by financial and scientific committee. In fact, after identifying the winners pilot project proposal of the first phase, a meeting was immediately scheduled to provide a detailed description of the impacts of climate change in North West territories of Italy, and to give a specific overview on how these impacts are expected to evolve in the future. In addition, time was also given to explain what climate data the CMCC would provide them, to have a complete climate profile in relation to the risks they had highlighted in the proposal drafting phase. Furthermore, a clear identification of the risk factors was provided so that a questionnaire could be submitted to them to incorporate the main critical issues in relation to the risk analysis factors exposure and vulnerability. Therefore, stakeholder involvement was a key activity, underpinning the pilot project throughout the period.

### 5.1. Strengths and limitations

The main limitations of the proposed methodology tested in the Call “Mutamenti” can be summarized as follows:

- the preliminary phase of planning activities took a long time, which meant that methodology had less time to implement planned activities on time;
- the lack of organizations/bodies/institutions already familiar with the theme of climate change meant that the specific project had less chance of success;
- Absence in the proposed methodology of monitoring and evaluation plan for the operational phase of the pilot projects.

The monitoring plan for the evaluation of the methodological framework proposed will be defined in the second phase of the case study test Call “Mutamenti”, characterized by the implementation of adaptation measures and the monitoring and evaluation of the effectiveness, where will assess the progress of each projects in the medium

and long term and the analysis of the goals defined in each proposals.

On the contrary, the main strengths of the methodology tested in the Call “Mutamenti” were:

- the bottom-up set-up, with the continuous involvement (and support) of all partners in the project. This led to greater involvement and understanding of the intended outcome within each of the 12 projects;
- the existing partnerships of the projects within the Call have been strengthened, making it easier to create working networks in prevision of future initiatives in each small municipalities involved;
- where project objectives were common, efforts were made to exchange information and best practices of each individual project to facilitate the success of all the projects (e.g., Municipality of Avigliana and Municipality of Almese with geo-hydrological impacts from precipitation events).

The validation of the proposed methodology through the engagement of the stakeholder involved in each project was substantially fundamental and was also verified by the technical and scientific committee (CMCC).

In addition, in accordance with the criticality mentioned above related to climate adaptation planning for small community as an under-researched field, considering the particular spatial distribution of population in the European context and the increase of climate hazards that are interesting the North Western Italian context, the results suggest that this methodology could be transfer to other territories with similar characteristics (e.g. small municipalities, inter-municipal and trans-regional territories) as well.

### Conclusions

Although many and growing efforts have been developed in Italy in recent years, there are currently no regulations that require the development of planning and design tools for adaptation to climate change at the local scale. At national level, the National Climate Change Adaptation Plan [19], which should set out strategic guidelines for the development of actions at local level, has not yet been published. Even today, one of the main limitations at national level is that the implementation of policies and actions for adaptation to climate change at this scale depends on the sensitivities of local administrations and the availability of economic resources, giving priority to a system of intervention in the city of post-emergence type rather than prevention. As a result of this approach, there are still few realities on the communitarian and national scale and especially for large urban centers that are characterized by plans for adaptation [18].

The development of the Climate Change Adaptation cycle for pilot projects development in small municipalities methodology for the territories involved in the case study test Call “Mutamenti” is useful to systematized and transferred, from the global level to the local level, the methodologies developed in the international frameworks, helping small-scale administrations to overcome the limits and lacks of implementation of adaptation actions. The Climate Change Adaptation cycle for pilot projects development in small municipalities methodology is a structure capable of linking objectives to the national and regional scale with the needs of preventing the effects of climate change at the local scale. The development of a method systematically designed and coordinated from the organizational and technical point of view by bodies with a high level of experience in projects of this type, has favored the fact that the different entities involved, although they are part of different territorial entities, work together rather than pursuing completely divergent visions, strategies and actions.

The construction of a transversal and holistic strategy to the different sectors that characterized the project proposals will ensure multiple benefits in the medium and long term, as well as a multi-scale response to the issue of adaptation to climate change.

Taking into account the great relevance in the adaptation process of the involvement of the local stakeholders and citizens, large effort in the methodology has also been posed for dissemination of the activities toward citizens and stakeholders. Specifically results have been disseminated through the development of an ad hoc on-line page dedicated to the case study test on the platform of Dataclime (link: <https://www.cmcc.it/it/mutamenti>), with the main information and results about each of the pilot project included within the application of the methodology. Download of dedicated pamphlets, including graphical and synthetic representations of the results in terms of climate hazards and risks, are available in the Dataclime platform, so as to give to stakeholders and citizens the possibility to easily access and understand the different risks factors that could influence the level of impacts due to climate change. In addition, different meetings have been organized by CSP (with the technical and scientific support of CMCC) to increase the level of local awareness on how to improve the climate change adaptation cycle at the community scale. In particular, a seminar was organized to give to stakeholders the opportunity to understand how to identify and apply to different sources of funding on a regional, national, or international basis. The method will support small municipalities in the development of demonstrative pilot actions aimed at increasing resilience at the territorial level. One aspect that could be beneficial to the success of future similar projects could be the consideration of specific partner requests during the early stage of the proposal. In other words, a range of competences could be requested in the preliminary phase of the project including - for example - a local administration, a research center dedicated to the predicted climate risks, and another body linked to the previous ones to provide additional technical support. Overall, however, this first phase has been successful, and creates the basis for the second phase of the projects, which will be characterized by more concrete local adaptation measures. Based on the results obtained by the study, it is very important to find a method to support the small municipalities by considering the gaps that are suffering, such as lack of knowledge, planning and design skills for climate adaptive systems, financial and human resources. The Climate Change Adaptation cycle for pilot projects development in small municipalities methodology was developed for the first time in Italy. The methodology has worked at inter-regional and inter-municipal level and considering simultaneously different geographic environments, small municipalities (under 20,000 inhabitants), and different sectors (such as built environment, infrastructures, agricultural system, tourism). In the study, it has defined a process to transfer the international methodological framework for climate change adaptation and risk assessment, creating partnership and supporting real implementation and construction of demonstrative adaptation pilot project adaptation.

#### CRediT authorship contribution statement

**Guglielmo Ricciardi:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Marta Ellena:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Giuliana Barbato:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Giuseppe Giugliano:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Pasquale Schiano:** Software, Validation. **Sara Leporati:** Project administration. **Claudia Traina:** Project administration. **Paola Mercogliano:** Conceptualization, Methodology, Supervision.

#### 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.

#### Data availability

Data will be made available on request.

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#### Appendix A

(See [Tables A1 and A2](#)).

#### Appendix B

(See [Tables B1 and B2](#)).

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