





Article

A Multi-Approach and Collaborative Pathway towards Designing Climate Strategies: The Case of Trentino, a Mountainous Region in Italy

Alessandro Gretter ^{1,2,*} , Anastasia Nikologianni ^{3,*} , Alessandro Betta ^{1,2,*} , Linda Lugli ¹, Lavinia Laiti ⁴  and Roberto Barbiero ⁴

¹ Research and Innovation Centre, Fondazione Edmund Mach, 38093 San Michele all'Adige (Trento), Italy; linda.lugli@fmach.it

² GREEN Groupe de Recherche en Education à l'Environnement et à la Nature, University of Aosta, 11100 Aosta, Italy

³ College of Architecture (ADM), Parkside Building, Birmingham City University, Cardigan Street, Birmingham B4 7BD, UK

⁴ Environmental Protection Agency, Autonomous Province of Trento, Piazza A. Vittoria, 5, 38100 Trento, Italy; lavinia.laiti@provincia.tn.it (L.L.); roberto.barbiero@provincia.tn.it (R.B.)

* Correspondence: alessandro.gretter@fmach.it (A.G.); natasa.nikologianni@gmail.com (A.N.); alessandro.betta@fmach.it (A.B.)

Abstract: Mountainous and rural territories are considered among the most vulnerable to the effects of the Climate Crisis. Their geographical and topographical conditions, together with the complexity of the system of relations between human and natural elements, amplify the impacts and risks associated with extreme climatic events. Therefore, the consequences on the socio-economic fabric are systemic and require an immediate response from all the actors in a region. Public administration and politics can play a pivotal role within the planning framework in contrasting the impacts of the climate crisis. This paper demonstrates the multi-level and multi-stakeholder approach applied during the development process of a regional adaptation strategy. The Autonomous Province of Trento has initiated an innovative approach to understanding and managing the effects of the climate crisis on its landscape and resources and has aligned the process of definition of its long-term strategy with the guidance provided by the EU Commission and the Italian Government. The methodology used is based on the tools provided by the Climate-ADAPT platform (in particular, the Regional Adaptation Support Tool—RAST), and the “impact chains” method is specifically implemented for climate risk assessment. The RAST is applied according to a multi-stakeholder and multi-level approach to capitalise on previously established and ongoing initiatives and working groups. The research suggests that the Climate Strategy model presented in this paper needs to be at the core of the broader framework adopted by the Autonomous Province of Trento and that it can represent an important example for other regions aiming to actively involve local stakeholders in acting for climate neutrality and resilience.

Keywords: climate strategy; regional adaptation policies; participatory policy design; Alps; Trentino



Citation: Gretter, A.; Nikologianni, A.; Betta, A.; Lugli, L.; Laiti, L.; Barbiero, R. A Multi-Approach and Collaborative Pathway towards Designing Climate Strategies: The Case of Trentino, a Mountainous Region in Italy. *Sustainability* **2024**, *16*, 4198. <https://doi.org/10.3390/su16104198>

Academic Editor: Alejandro Javier Rescia Perazzo

Received: 7 February 2024

Revised: 7 May 2024

Accepted: 9 May 2024

Published: 16 May 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

There is no doubt about the effects of the environmental crisis and the need for sustainable strategies at the local as well as national, and international levels. The climate emergency applies to all scales, national, regional, and local as well as governments [1]. For several years, the discussion around sustainability and the climate crisis was focused on mitigation and isolated topics such as energy reduction, the built environment, materials, and transport. However, it has been more than a decade that cities have been recognised as key players in a global climate governance system [2,3]. The significance of both peri-urban and rural territories should be recognised within the governance processes. The provision

of agro-food and ecosystem services is, in fact, crucial for the well-being of citizens, and international agencies, such as FAO, clearly identify some potential trajectories to deal with climate emergency [4].

The need for systemic change and the development of holistic strategies that embed wider ideas, such as landscape, climate characteristics, social cohesion, heritage, and cultural elements, as well as environmental aspects in cities and regions, is now apparent.

The latest climate reports mention that, as predicted, the frequency and severity of weather and climate extremes are increasing and that the past decade has been the hottest decade on record [5]. In addition, the hottest year was beaten nine times during the ten-year period [5,6], a fact that is scary and worrying, especially when supposedly initial measures have been in place for several years at a global level. The spatial scale is now recognised as how climate challenges can be adapted to, and therefore, landscape design and planning are very significant on local and national scales.

This paper aims to discuss the process of development of a climate change adaptation strategy in the Autonomous Province of Trento (from now on referred to as Trentino), as well as the opportunity to provide a framework for climate-related actions to be applied in other areas. In fact, the goal of this paper is to collect evidence of a series of activities that were not designed under a scientific approach or to apply a defined methodology on climate change strategy.

Using the expertise of institutions and local authorities in the wider area of Trentino as well as national and international projects developed in the area (e.g., SATURN, and others within the financial support framework of EIT Climate-KIC [7] etc.), the focus is on a framework that will not only address policy or the built environment and finances, but a series of adaptation measures that can be implemented by different sectors (farming, forestry, tourism) covering very different landscape typologies within the region, and including them in various sectoral plans and programmes. In order to pursue its objectives, the civil servants adopted the general methodology proposed by Climate-ADAPT (in particular through the adoption of the Regional Adaptation Support Tool—RAST) together with the implementation of the “impact chains” method specifically for risk assessment [8]. The adoption of the RAST tool according to a multi-stakeholder and multi-level approach permitted, in fact, the capitalisation of previous and ongoing initiatives and working groups. The utilised approach could be of inspiration to other territories, especially those matching the character of rural locations, to gather a wider range of data, information, and indications on how to design and implement their local climate strategies.

2. Literature Review

With the European Commission adopting the new EU Strategy ‘on adaptation to climate change’ on 24 February 2021 [5], the pathway to prepare for the significant impacts of climate emergency has been set out. In addition, the Intergovernmental Panel on Climate Change (IPCC), in its Fifth Assessment Report, has identified cities as primary areas at risk from climate change [9], highlighting that environmental and climate challenges have major effects in urban contexts. Although discussions on climate emergency were initiated more than 30 years ago, when several nations agreed that development should be sustainable (e.g., 1992 Earth Summit) [10], adaptation was not considered that significant at the time. On a political level, agreements focused on the ability of countries to achieve positive social and economic development considering environmental degradation [10], but adaptation measures were added to the EU Member States policy agenda after the turn of this century [11], encouraging the development of National Adaptation Strategies.

The interactions between climate change, agricultural productivity, and socio-economic factors are complex, underscoring the need for comprehensive analysis and adaptation strategies to address the challenges faced by the agriculture sector in Europe. The main climate-driven impacts of climate change on agriculture are related to changes in temperature, precipitation, extreme weather events, and loss of soil quality and biodiversity. Climate change also affects agroecosystems and contributes to the increased release of greenhouse gases and

air pollutants. The Mediterranean basin is particularly susceptible, and the implications of productivity loss will strongly affect food security and food prices in Europe [12].

A decade ago, Hakelberg [3] argued that climate policy had been a ‘voluntary task for municipalities’ in most of the European countries, as higher political levels had little impact on local climate strategies [3]. Today, the situation is very different, with many countries and cities having declared climate emergency and the carbon targets becoming stricter. Therefore, there is a lot of discussion on planning, finances, public finances, and insurance, but there is still little mention of landscape and how important it is to a holistic systemic change integrating environmental, cultural, and social characteristics of the land instead of just focusing on infrastructure and finances. At a global level, there are frameworks that investigate spatial planning and climate emergencies without focusing on landscapes and their social and cultural characteristics, and they often employ sector-oriented approaches to tackle specific gaps in relation to climate change [1,13,14]. Several frameworks have been developed by international and national institutions dealing with spatial scales, but they usually tackle planning or policy and do not consider how these areas will be designed. For example, climate-related planning frameworks have been developed by the International Institute for Environment and Development (IIED) [15], whilst the United Nations Development Programme (UNDP) and the United Nations International Strategy for Disaster Reduction (UNISDR) have focused more on policy and adaptation towards urban resilience [9]. Planning for climate adaptation emerges fast, especially at a ‘geo-political’ scale [14]. However, data show that the existing adaptation plans do not provide comprehensive results on adaptation [14]. Following scientific results, Preston [14] states that the majority of examined plans were developed by the governments and, in many cases, by a single department (environment or sustainability) with only a few cases to have developed cross-government committees. Therefore, the gap identified by this paper relates to the development of climate adaptation strategies in relation to spatial scale, decision-making, the environment, and the climate crisis.

The need for systemic change and a shift of the focus ‘from understanding the problem to developing solutions and to move from planning to implementation’ is highlighted by Kondrup et al., [5] who state that the 2013 Climate Change Adaptation Strategy was a positive outcome, but it also needs to expand on local level, considering environmental elements, nature-based solutions, and community needs. Therefore, the strategies developed at a local authority level need to incorporate resilience and adaptation actions into their future plans and emphasise the significance of public engagement and awareness [11]. The notion that an effective climate adaptation plan incorporates social and decision-making processes has started to emerge [14] and allows for more room for the landscape needs to be seen as a collective of issues in relation to strategies developed in cities or regions. As Zhou et al. [9] suggest, ‘local authorities must improve their adaptive capacity’ if we are to respond to the impact of climate emergency, and this paper examines ways in which strategies can be developed at a local level. Vulnerable cities were among the first to include resilient strategies in their plans and interact with regional and national strategies as well as community mechanisms [16]. However, nowadays, all cities need and must develop sustainable and climate strategies, and there are cases where ‘pioneering cities have not only inspired other municipalities to act but have also shown leadership vis-à-vis their national governments [2].

Climate strategies and policies cannot be considered a ‘luxury’ [3] but a necessity we cannot do without. There are cases where countries have been pioneers in matters relating to the climate crisis (e.g., France, UK). Especially in the UK, there have been suggestions that sustainable development strategies can provide frameworks of principles to be applied to every policy and in every department [17]. Further research states that local action on climate emergencies can be enhanced by transnational municipal networks [3,18] since they act as a support mechanism for the exchange of knowledge and policies between cities. The adoption of a climate strategy on a local level is ‘normal and appropriate’, as the Climate Alliance and CCP transnational municipal networks try to explain [3], and

not something that is extraordinary. Researchers and scientists pointed out a while ago that local scale is also related to spatial planning and that the latter has a major role to play in climate change adaptation [1]. Initially, local authorities tended to focus their actions on environmental change in reducing greenhouse gas emissions [1]. However, it is encouraging that more holistic approaches have started to emerge. Several limitations in implementing climate-related actions have been experienced by local governments, such as a lack of political, professional, or technical support [19,20]. As expected, collaborations at a local or governmental level are necessary, and as far as this paper is concerned, climate spatial strategies have not yet been developed satisfactorily. Biesbroek et al., 2010 [11] mention that climate-sensitive policies across different scales require an ‘active role for the national government’ [11], emphasising the importance and/or support needed for cities and regions to develop holistic climate strategies.

Sustainable Landscape and Strategies

The definition of sustainable or resilient landscape can vary depending on the approach used, however, for the purposes of this paper we quote a definition provided by The Office of Sustainability at the University of New Hampshire that mentions sustainable landscape as ‘ecologically healthy, economically viable, aesthetically pleasing, and equitable in terms of access’ [21]. In addition, the authors align with the Council of Europe’s definition of landscape as an area ‘whose character is the result of the action and interaction of natural and/or human factors’ [22], meaning the social and cultural characteristics cannot be overlooked when planning or designing, but can form a way to enhance the sense of place. To build on this approach, several authors underline that landscape can be perceived as a multi-functional element that encompasses a variety of dimensions and requires a holistic approach [21,23–26]. According to the Renewed European Union Sustainable Development Strategy, the main objectives of sustainable development are social cohesion, environmental protection, equity, and economic prosperity [21], but somehow several years later, there is not a broad portfolio of strategies that incorporate all these elements in relation to cities and the landscape, especially when it comes to graphical representation.

As Clayton and Bass [10] had identified two decades ago, ‘the achievement of sustainability in national development requires a strategic approach, which is both long-term in its perspective and integrated or ‘joined-up’ in linking various development processes, so that they are as sophisticated as the challenges are complex’. Developing a climate strategy in relation to the landscape is not a new topic, but one that has been thought about and discussed for a long time. However, how these strategies interact with the landscape, as well as their social and cultural characteristics, are still in motion. Even though sustainable and environmentally friendly landscapes are now widely discussed, and climate strategies in cities are a necessity, there is often the perception that these are different elements that do not necessarily need to interact with each other. Mallick [27] explains that there are several researchers who have dealt with urban resilience in relation to social and environmental perspectives; however, ‘urban resilience with sustainable development is still a major research gap’ [27]. Looking into how sustainable landscapes connect to climate strategies, the authors align with Vileniske’s [21] suggestion that a sustainable development strategy considering the landscape must incorporate cultural, economic, environmental, and social elements and therefore a sustainable or climate strategy needs to incorporate such ideas in their plans. Therefore, one wonders, why is this not the norm yet? How is it possible that, as Xia and Cheng [28] identify in their research, village developments do not pay enough attention to the protection of the environment or the avoidance of pollution and damage to natural resources in the process of rapid urbanisation? Accordingly, the relevant economic sectors must shape their business models and strategies towards a novel paradigm, having a future-proof and climate-resilient socio-ecological system (especially for agriculture, heavy manufacturing, and tourism sectors).

Working towards sustainable and environmentally friendly landscapes is not an easy task. However, it would be worth exploring further to develop climate adaptation

strategies on local or national scales. However, to achieve such an approach, the current professional and policy frameworks need to shift from the notion that climate change strategies' main aim is to address 'a level of investment that appropriately balances the costs and benefits of reducing emissions' [29], without any further consideration on the urban or rural surroundings. Girard [30] is correct when he states that when it comes to local developments, a cultural planning approach is important, as it 'promotes a transdisciplinary perspective' [30]. However, current plans often focus on policies or frameworks that do not embed the wider ideas of the landscape and the environment.

Referring specifically to agricultural landscapes, it is worth noting that the suggested transdisciplinary perspective needs to be stressed further, given the complex and intricate interrelations between biotic and abiotic elements. At the European level, adaptation policies on agriculture and the primary sector are relatively fragmented despite the adoption of the common framework related to CAP (Common Agricultural Policy). See Figure 1.

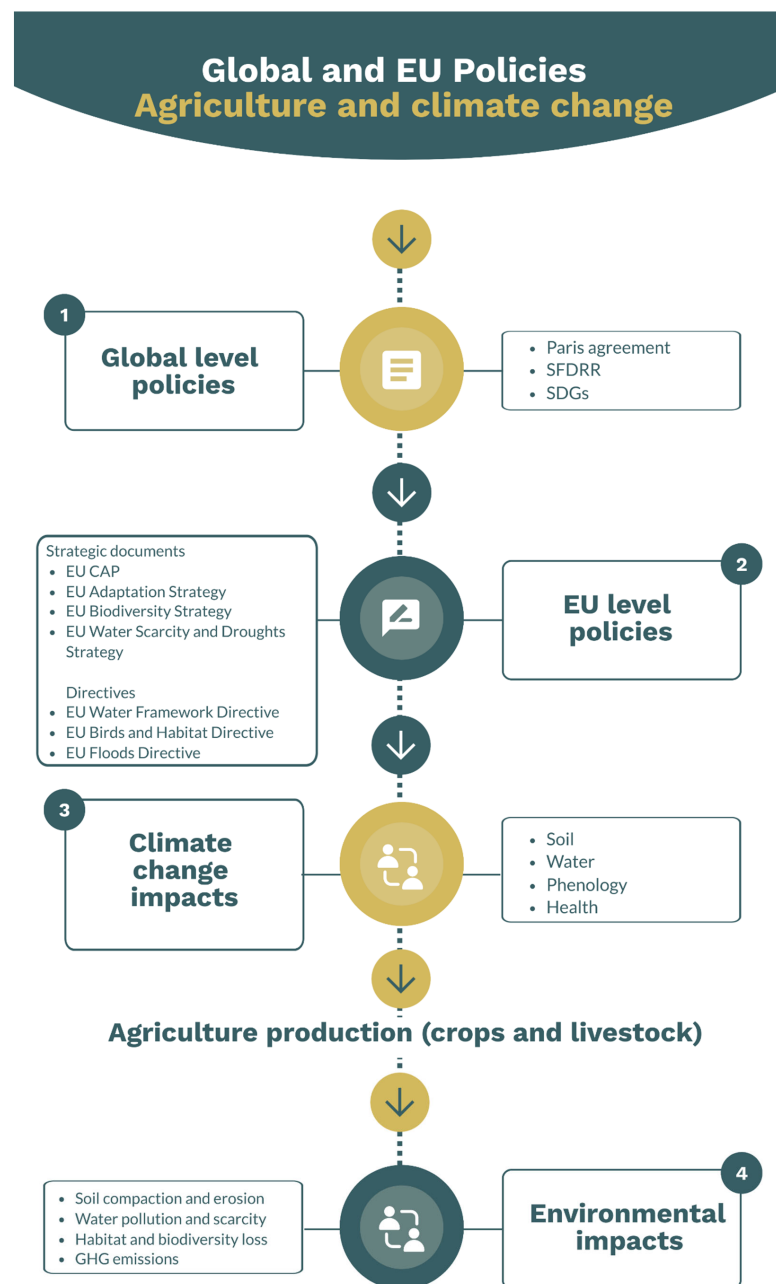


Figure 1. Overview of the International EU policy framework for climate change adaptation in the agriculture sector (adapted from EEA, 2019 [12]).

The climate adaptation plan of the agricultural sector needs to tackle several challenges connected to global rising temperatures or increased frequency of extreme events. Moreover, the same climate drivers could lead to opposite effects across Europe (e.g., an increase in average temperatures could lead to longer harvest seasons in Northern Europe while severely stressing plant resistance in Mediterranean countries). An increasing variation in crop yields due to growing uncertainty in climate and rainfall patterns is expected, together with the wider diffusion of pests and diseases, further weakening and fostering vulnerability in the sector. Current managing practices in EU agriculture can possibly lead to negative impacts on soil, water, and air quality [31,32].

Among the adaptation measures and policies that are included in the 2021–2027 framework of the CAP, crop rotation requirements have been added to enhanced conditionality, i.e., cross-compliance. Within Pillar 1, eco-schemes have been introduced (including agri-environment-climate measures) and are required to be implemented, yet Member States are left free to select and identify measures to adopt even though their specific inclusion allows Member States to finance technical and capacity-building measures [33]. Within the new framework, adaptation is a specific objective and 30% of the national budget for rural development must be invested in the ‘greening’ processes (agri-environment-climate measures, investments related to the environment and climate, forestry measures, organic farming, and Natura 2000 sites) [12]. Various Member States (e.g., Malta, Romania) mainstreamed climate change adaptation into national agricultural policies, and several Member States (e.g., Slovenia) developed specific adaptation strategies for the agriculture sector [34,35].

The effects of climate change on mountainous ecosystems have been revealed worldwide since the early 2000s, on a faster track than in other territories and, at the European level, in the Alps [36]. The rapid transformation in climate and natural elements that have been recorded puts pressure on the specific elements of mountain landscapes and the permanent or temporary human communities living in them [37]. These challenges can also provide an opportunity, prompting an accelerated transition to different models and adaptive solutions [38], and in some territories, specific solutions have been formulated, and some of them have already been implemented [39]. It must be noted that the strict relationships between both the primary sector and tourism are pivotal within many mountainous communities, and processes to bridge potential conflicts or collaborations have been tested since the earliest occurrences [40].

A consensus on the political level of different institutional bodies (from National Government to Municipalities) to adopt a common approach for territories and sectors facing the same challenges and shared solutions is becoming apparent [41]. This approach clearly operates within the Alpine arc, where the attention to climate, agriculture, nature, and economic sectors is being handled by EUSALP and has been at the centre of the political debate for a decade [42].

3. The Study Area and the Context of Reference

The Autonomous Province of Trento (also known as Trentino; NUTS 3 level region) is situated on the southern side of the Alps. It occupies an area of 6207 km² and is predominantly mountainous, with strong variations in climatic conditions. Almost 70% of the territory lies above 1000 m. Population density is relatively low, with 542,050 inhabitants (as of 1st January 2023 [43]), resulting in an overall density of around 89 inhabitants per km². However, it should be noted that a significant portion of the territory is unsuitable for permanent habitation due to altitude, morphology, or geographical constraints. As a result, most of the population is concentrated in urban areas located in the lower valleys. Despite having birth rates higher than the national average, the population is growing slowly, and population ageing is widespread in the most remote areas.

The Province of Trento is a pivotal node of the European TEN-T network due to the location of the Alpine arch and the fact that the ‘Brennerpass’ is the lowest Alpine crossing. Trentino’s territory is fragmented by major transport infrastructures, such as the A22 highway and the Brenner railway, connecting the industrial core of Pianura Padana

with Germany and Northern Europe. Tourism contributes to a relevant share of the overall GDP (10% of the total share, 1.3 billion € in value) of the area with 19,796,605 overnight stays in total (2022 data). The industrial and tertiary sectors are the primary drivers of the economy, accounting for over half of the workforce and GDP production. Although the primary sector accounts for only 5.5% of the total GDP, it plays a crucial role in shaping the landscape and contributing to the area's touristic attractiveness. Covering 147,000 hectares and representing 12,000 farms and companies, agriculture focuses on high-value-added crops such as grapes, apples and berries. The complex topography, with forests covering 50% of the Province, makes the area vulnerable to natural hazards typical of Alpine regions.

3.1. *The Impacts of Climate Change in Trentino*

Temperature observations from local weather stations show that annual temperatures in Trentino have increased to approximately 3 °C compared to the pre-industrial era (1850–1900) and by about 1.1 °C between 1961 and 1990 and 1991 and 2020. Regional warming has been almost twice as high as the global average. The annual rainfall exhibits partially contrasting trends that are not statistically significant, while notable modifications in seasonal amounts have been observed. Snowfall, snow cover and duration of snow cover on the ground have significantly decreased due to rising temperatures. Future climate scenarios predict that the warming trend will continue, regardless of the emission scenario, with a further increase of 1 to 2 °C expected until 2050 compared to the 1981–2010 average. Precipitation projections are affected by significant uncertainty, but while it is likely that the total rainfall amount will remain stable, extreme precipitation events, as well as heatwaves and droughts, will probably become more intense and frequent [44].

Relying heavily on agriculture, tourism, and forestry, the Province of Trento is facing multiple climate risks that are expected to worsen in the future, as outlined for Alpine regions in [45]. While acknowledging the risks to human health posed by increasing heat stress and natural hazards, the growing impacts of water scarcity on drinking water supply, crop irrigation, and hydropower production, and the negative consequences of natural snow decline for winter ski tourism should not be overlooked. Agricultural production will also be impacted by late frosts, storms, and pests and diseases facilitated by climate change. The shifts in species distribution and the spread of invasive species, as well as the worsening of forest disturbances (e.g., major storms, droughts, insect outbreaks), pose a threat to aquatic and terrestrial ecosystems and to the provision of essential ecosystem services.

3.2. *The Urgency to Adopt a Proper Climate Policy*

In view of the above, it is crucial to urgently address the current climate crisis in the Trentino region, including both mitigation and adaptation measures to achieve climate neutrality and resilience in the region while protecting and supporting both environmental systems and socio-economic sectors.

Following the first EU adaptation strategy, the National Strategy for Adaptation to Climate Change (SNACC) was adopted in Italy in 2015, followed in 2016 by the beginning of the long elaboration process of the National Plan for Adaptation to Climate Change (PNACC) [46] that led to the publication of a first draft in 2018 and finally to its recent definitive approval at the end of 2023, with great delay concerning the needs of the Italian regions and autonomous provinces for concrete guidance and coordination in the elaboration of their own adaptation policies. In recent years, the definition of adaptation policies at the regional level has been carried out by some pioneering Regional Authorities with the support of European projects (e.g., LIFE Master ADAPT [47]), ministerial training programs (e.g., CREIAMO PA project) [48] and scientific and technical collaborations at regional, national, and trans-national level. Specifically to the Alpine context, what concerns the formulation of adaptation policies are activities and projects of the EU Strategy for the Alpine region (EUSALP) and Alpine Convention [49] networks in the fields of climate change mitigation and adaptation as well as nature and biodiversity conservation (through adopting a specific initiative named Alpine Climate Board).

The path towards the adoption of a Provincial Strategy for Mitigation and Adaptation to Climate Change for the Autonomous Province of Trento takes shape in the context described above. The framework provided by national guidelines and overarching/superordinate national plans regarding adaptation appears partially incomplete, despite the growing number of strategy examples from Italian, Alpine and European regions. A dedicated work program, named “Trentino Clima 2021–2023” [50], was firstly approved by the provincial government in 2021 (Decree n.1306 of 7th August 2021). The Climate Adaptation Strategy that is presented in this paper represents one of the implementation objectives of the already approved Provincial Sustainable Development Strategy [51]. It will identify the measures to be included in future sectoral programmes and plans to contrast climate change and its impacts in Trentino. The Provincial Environmental Protection Agency (APPA) is responsible for the overall coordination of the Strategy development, while technical and scientific support is provided respectively by the provincial departments represented in the Provincial Table for Coordination and Action on Climate Change and of the provincial research institutions that are part of the Scientific Committee. In addition to these two technical and scientific bodies, the Provincial Forum for Climate Change is an informal space to discuss and promote coordinated cultural, informative, educational and citizen engagement initiatives in the Province of Trento.

4. Methodology

4.1. Framework: Climate-ADAPT RAST Tool, Impact Chains Method and Multi-Level Cooperation

The regional government of Trentino opted for a collaborative process to develop its local climate strategies connecting across the different public departments and involving research institutions. This newly established process, despite taking additional time, has started a transformative approach to defining a local climate strategy. The strategy presented by this study is developed through a multi-level cooperation process informed by the methodological framework derived from the indications of the European Commission and the European Environment Agency (EEA), provided via the European Climate Adaptation Platform Climate-ADAPT [52] and its Regional Adaptation Support Tool (RAST) for adaptation planning by regional authorities. The Climate-ADAPT platform [52] extracts and collects the best available knowledge concerning climate impacts, risks and vulnerabilities, data and indicators, as well as results from research and innovation projects, useful tools and ongoing adaptation practices in Europe. The RAST has been specifically designed inside Climate-ADAPT [53] to assist policymakers at the sub-national level in developing, implementing, monitoring, and evaluating climate strategies and plans step by step. The RAST is based on the concept of the adaptation policy cycle and foresees an iterative approach in the application of its six main steps: (1) Preparing the ground for adaptation, (2) Assessing climate change risks and vulnerabilities, (3) Identifying adaptation options, (4) Assessing adaptation options, (5) Implementing adaptation and (6) Monitoring and Evaluating adaptation. It should be clarified that this tool is not intended to produce a tailor-made climate adaptation strategy but to highlight key issues of policymaking and provide access to relevant strategic and financial resources. Accordingly, each regional or local authority will develop a highly customised approach at every stage of the process, as is the case of the Autonomous Province of Trento. The conceptual framework of “Impact Chains” was adopted in relation to the climate risk analysis, which is required for the identification of proper adaptation measures (steps 2 and 3 of RAST above), as recommended. The framework works in line with the IPCC risk assessment approach that splits climate risks into three components: hazard, vulnerability, and exposure. At an international level, these aspects have found in recent years a proper methodology of description, as also proposed in Italy by different public authorities, such as the Piedmont region [54].

Climate ‘Impact Chain’ is a representation of how climate change drivers (rise of global temperature, increased variability of rain patterns, and so on) affect and propagate in terms of cause-effect through a selected system or sector (territory, supply chain, ecosystem etc.), inducing direct and indirect impacts ultimately associated to a specific climate risk. Impact

Chains allow us to identify triggers, barriers, hidden links, or affected components of the system, enhancing the understanding of how climate-related risks can have multiple effects and what the levers on which to act as a priority to reduce risk and increase resilience are. Impact Chains are usually developed in a participatory manner, involving both stakeholders and experts, and are characterised by a mixed nature, combining qualitative and quantitative information, depending on the risk assessment stage and on the availability or not of quantitative indicators and models [55].

This approach, gaining a wider application in several PAs across Europe and worldwide, has been used as well in Trentino as the centrepiece of the definition of the local Climate Strategy for what adaptation matters.

4.2. Tools and Approaches

To design the Climate Strategy for Trentino, the local authorities addressed the topic of mitigation and adaptation in a subsequent time frame. The adoption in 2021 of the Provincial Environmental Energy Plan (PEAP) [56], which covers the period until 2030, contains a series of mitigation measures targeting different economic sectors or activities of public relevance (such as energy and mobility). PEAP as a document has been used as a starting point for the activities and as a “foundational” document for the activities focused on adaptation that followed. Considering that a multi-sectoral portfolio of adaptation measures needed to be developed from scratch, local authorities have developed a complex process based on the integration of different tools. The methodology underlying the development process of the climate strategy for Trentino is based on both qualitative and quantitative methods involving a wide range of actors, including public administrations, research institutions, and local NGOs. The framework is aimed at creating a link between governmental bodies, experts, and the citizens (in particular youth) through surveys, workshops, and educational and communication activities. The selected groups of stakeholders hold different levels of involvement, with the objective of targeting the wider collection of data and information to allow the co-design of valuable Impact Chains and adaptation measures for Trentino.

The overall participatory process to co-design the Climate Adaptation Strategy has been planned on multiple levels as follows:

- First level: involvement of provincial structures/departments and scientific institutions to highlight and strengthen the knowledge basis on climate change impacts and risks and adaptation measures.
- Second level: involvement of other stakeholders for validation, identification of priorities in terms of perceived risks and preferred measures, and integration of measures.
- Third level: The “typical” participation phase is based on the Strategy’s first version, with workshops and consultation initiatives dedicated to the validation and adjustment of the planned measures and strategies to be undertaken.

The first and second levels have already been implemented in 2023, while the third is planned for late 2024, aiming to operate towards the refinement of the final version of the Climate Strategy to be officially delivered later during the year.

Three main clusters of activities were put in place by the Autonomous Province of Trento to implement the first and second levels of the participatory process, as presented in Figure 2, including a general citizen survey, a set of youth conferences on climate, and a set of roundtables involving local experts and researchers. These activities informed each part of the strategy and offered precious mutual insights. While the citizen survey was aimed at the general understanding and perception of the climate crisis and of the actions needed to contrast it by the entire population, the youth conferences seek to include the specific perspective of younger generations and propose their ideas on the political and policy agenda. On the other hand, experts have been mainly involved in thematic workshops, which have given insights into specific climate risks and possible adaptation options for the most relevant environmental and socio-economic sectors in the region.

Three levels strategy

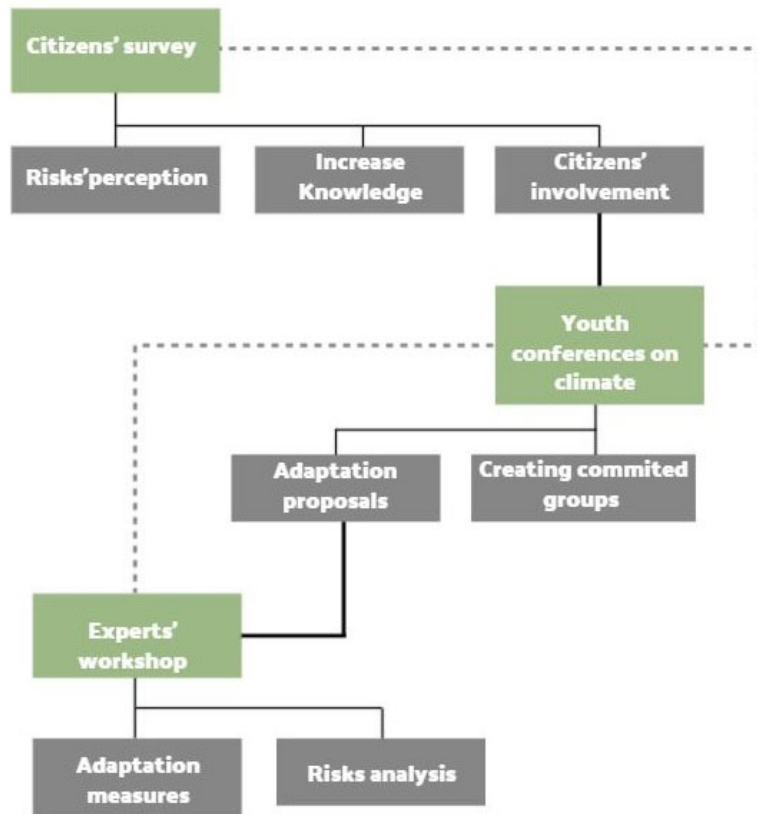


Figure 2. Flowchart of the activities put in place for what concerns the participatory process towards the co-design of the adaptation strategy of Trentino. Clusters of participation activities correspond to light green elements, while the objectives/results pursued are in dark green.

The framework described above is the basis for the multi-level, multi-stakeholder cooperative approach chosen by the Autonomous Province of Trento and corresponds to the implementation of Steps 1 to 3 of the adaptation policy cycle as given in the Climate-ADAPT RAST.

4.2.1. Survey on Citizens' Perception

As part of the activities for the “Trentino Climate 2021–2023” [50] work program, an online survey among Trentino’s citizens was launched by the public administration between March and June 2023. The goal of this consultation initiative was to inform the framework for the future implementation of the Provincial Climate Change Mitigation and Adaptation Strategy according to the citizen’s perception of climate risks and action priorities while supporting the same time education and awareness on the issue of climate emergency among the population. The survey, which consisted of a Google Form and included 20 single and multiple-choice questions, was promoted by APPA through institutional press releases, newsletters, and websites. Around 900 participants answered the online questionnaire “Cambiamenti climatici in Trentino. Quanto ne sai?” (Climate Change in Trentino. How much do you know? [57]), providing a reasonably representative sample in terms of gender, age group, education, occupation, and territory of residence. However, it

is very likely that those who did participate in the survey were among the most motivated and climate-conscious citizens and that the results are, at least partially, biased accordingly.

4.2.2. Youth Conferences on Climate Change Adaptation

The Autonomous Province of Trento has given particular attention to young people when preparing its strategic policy documents. This approach has been further enhanced in recent years when dedicated activities have been carried out for pupils at both high school and university levels. Specific well-attended laboratories/workshops were organised in local schools where the students have been discussing and drafting solutions for both the Sustainable Development Strategy (connected with the local application of the Agenda for Sustainable Development Goal and already approved in 2021) and the Climate Strategy within Trentino. The support for the active representation of young people in relation to climate change topics has been continuous and consistent since 2011.

Beyond the general focus on communication and climate awareness, specific attention has been given recently to the consultancy role that youth can play. In 2020 and 2023 two groups of young people from local communities across the region, selected among those who applied for participation, took part in a co-creation process promoted by APPA where confirmed scientific data on climate change and its impact on Trentino, as well as possible solutions, were offered to them with the support of local experts. Afterwards, the youth groups had the opportunity to work autonomously in smaller self-organised groups to identify topics of relevance to their territories and propose original sets of potential adaptation measures to be presented both to the local and the provincial councils for their evaluation and possible adoption/consideration for inclusion in climate strategies and implementation.

4.2.3. The Experts' Workshops

The experts' evaluation was the Third Level of the wider participatory and co-design process described above (Figure 2).

For this APPA worked in close partnership with Trentino School of Management, but most of the workload for several sectors was carried out by FEM, which focused mainly on climate risks related to natural resources and to the primary sector.

Drafting the portfolio of possible adaptation measures required the active participation in a series of workshops in the presence, followed by offline refinement and review activities, of scientific and technical experts from provincial departments and scientific institutions across many different sectors such as water resources, water quality, tourism, aquatic and terrestrial ecosystems, forest ecosystems, alpine fauna, human and animal health (including zoonoses), and the agro-food sector (viticulture- wine value-chain, apple and other fruit trees, animal husbandry and aquaculture) to mention the most important ones.

About 120 experts attended the workshops in the selected sectors in total.

The 22 workshops organised by TSM and FEM envisaged four phases according to the approach of the Impact Chains [58].

In the first phase, the purpose of the broader project and the meeting's agenda were explained to the participants. The reference context and the founding concepts of the Impact Chains methodology (Climate Risk, Hazard Impacts, Exposure, Vulnerability) were also presented (see Table 1 for definition).

In the second phase, the most significant climate hazards that affect the Trentino region were selected amongst those proposed by the CMCC (Centro Euro Mediterraneo per i Cambiamenti Climatici) [59], resulting in a pool of possible climate hazards. The highlighted hazards were ranked by relevance, and the focus was turned on the top three/four hazards to have the opportunity to analyse them in depth during the workshops. The purpose of the third phase was to identify the vulnerabilities of the Trentino region and elaborate on adaptation measures to limit the impacts of climate change. Participants were asked to use brainstorming techniques and Post-it notes to construct the Impact Chain diagram by identifying impact, exposed subjects, and vulnerabilities.

Table 1. Definition of the basic concepts that underpin climate “impact chain” methodology, as used for climate risk analysis and identification of responding adaptation measures. Climate-change-related risks are considered to be the result of the combination of hazards (or impacts) and factors of exposure and vulnerability.

Adaptation Measure	Vulnerability	Impacts	Exposure	Climate Hazard	Risk
Proposals for measures acting to reduce exposure or vulnerability factors (and risk, as a result)	Multiplying factors for impacts (specific or systemic weaknesses)	Product of climate hazards on the specific exposed factor	Factor on which hazard may act and produce negative effects	Climate change trends or abrupt variations at different levels (global, regional)	Driver related climate risks

In the fourth and final stage, the experts suggested possible adaptation measures and specified several actions for each of them, that were also classified according to the five categories proposed by the Climate-ADAPT framework (Governance, Economics and Finance, Technological Innovations, Nature-based Solutions, and Knowledge and Behaviours Change), as well as to their urgency of implementation and time horizon (short, medium, or long term). Moreover, the implementation priority and feasibility of each action were indicated.

5. Results

The different schemes and documents developed within the process of definition of the proposed strategy are all linked to the idea of a comprehensive approach to climate challenges that bring together research and practice, as well as all landscape actors. The effectiveness of the approach used was guaranteed by dividing the results achieved and potential measures into three different documents based on the focus and interest of the group of experts who developed them. This then allowed each phase planned for the drafting of the strategy to draw information from the previous ones, thus strengthening itself in succession.

These results were then used as a preliminary framework to inform the experts’ work towards the proposal of possible adaptation measures. In fact, the key objectives of the team involved in the development of the Climate Strategy is to establish a series of actions and initiatives, such as a set of recommendations, organised according to the Climate-ADAPT [52] methodology, after adopting the above-mentioned methodologies and tools.

5.1. Adaptation: Citizen Survey

Considering that the citizens’ survey was not designed according to the criteria of scientific research, and therefore cautiously assuming that citizens already sensitive to the climate-crisis issues were more engaged than others; the results collected have demonstrated that the general knowledge of the actual climate crisis impacts in Trentino among the public is not particularly high. In addition, the understanding of climate-change-related terminology is still challenging, and Trentino Clima 2021–2023, the provincial work programme regarding such issues, is not well known. However, the survey’s participants have shared widespread concerns about the impacts of the climate crisis in their territory and the need for urgent climate action at the provincial level, with an impressive 88% and 92% of the sample, respectively. In relation to the adaptation effort needed to address the impacts and risks of the climate crisis, the participants pointed to water resource management as a priority, particularly for its use in agriculture and animal husbandry, an outcome likely influenced by the prolonged drought situation that hit northern Italy and Trentino during the years 2021/2022 and early 2023. The management of natural hazards related to extreme events (such as flash flooding, landslides, and wildfires) received fewer votes but still ranked high. Challenges related to the protection of biodiversity, ecosystem services, and human health followed.

The analysis of the sample stratification according to the age and gender of the participants has revealed a lower level of awareness and concern among younger citizens (under 18 s), in contrast to very high values in the 18–35 age group (i.e., typically the most affected by eco-anxiety [60], which particularly affects young adults who are active self-learners and well-informed). This knowledge gradually decreases in the over 70 s group, but they remain more aware than the youngest (under 18 s). In general, female participants expressed greater concern and a perception of the urgency of climate action (Figure 3), in agreement with previous scientific studies and surveys, that also report greater awareness of individual behaviours' role and more willingness to transform lifestyle and consumption habits accordingly for women than for men. More details are available online in Italian Language in the complete report [57].

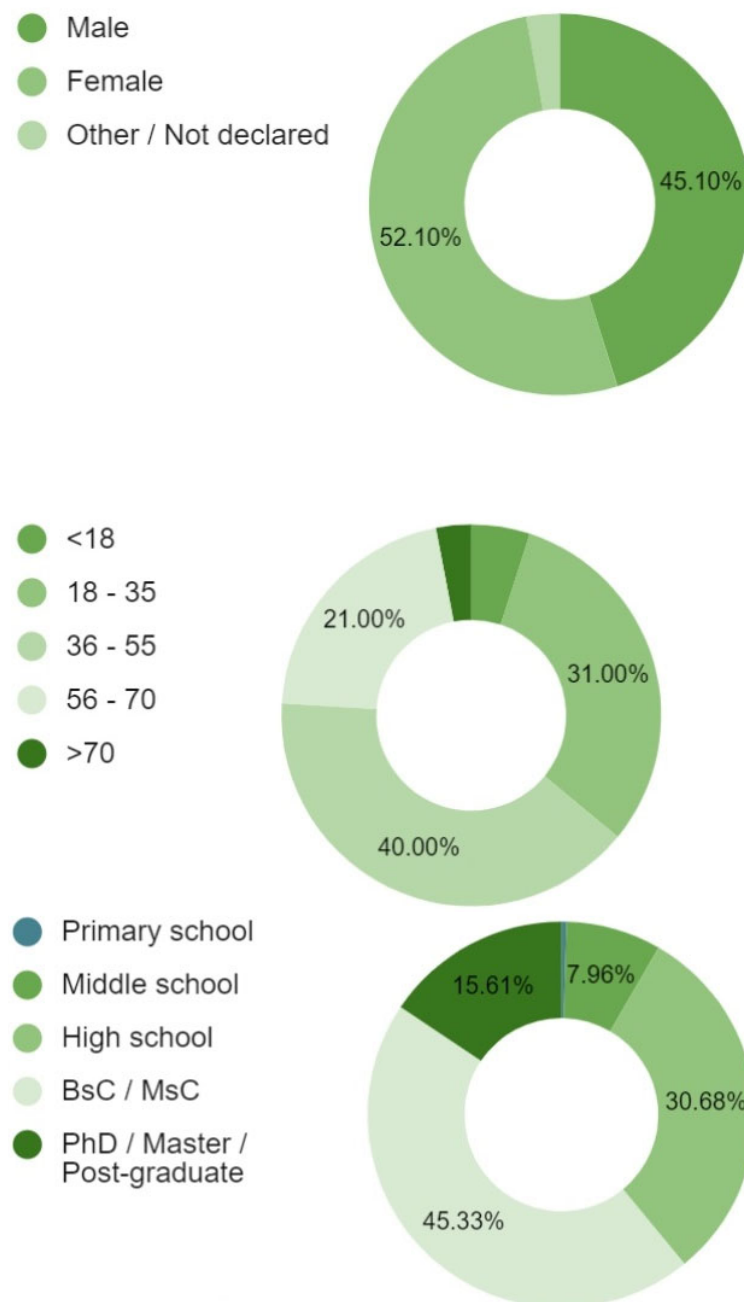


Figure 3. Overview of gender, age groups, and education level of participants to the survey.

Aggregate statistics and histograms results were obtained using the Google Forms online application (<https://www.google.it/intl/en/forms/about/>, last accessed on 31 July 2023),

while the answers' stratification according to demographic information was investigated by implementing pivot tables in Google Sheets online application (<https://www.google.it/intl/en/forms/about/>, last accessed on 31 July 2023; see Figures 4 and 5). The following graphs present the main findings in some of the key questions of the survey.

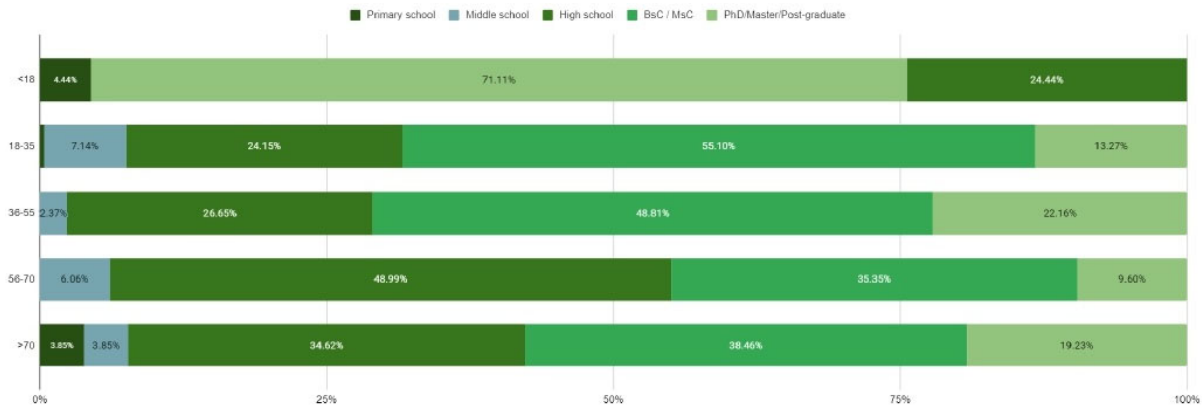


Figure 4. Education level for each considered age group.

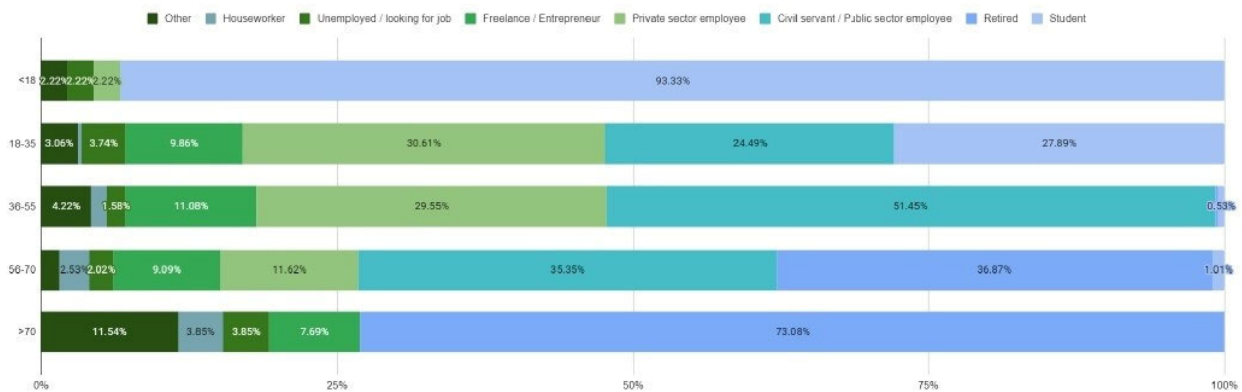


Figure 5. Profession by age group of respondents and average education level among the entire panel.

83.4% of the respondents were very worried or extremely worried about the impact of climate change on their own territory (Figure 6).

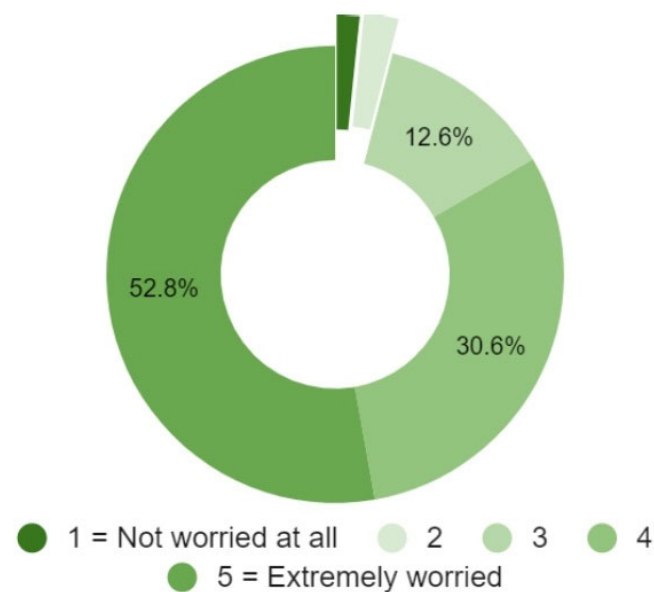


Figure 6. The main findings are from some of the key questions in the survey.

Each respondent has been asked to indicate three (maximum) sectors considered as critical that will be impacted by climate change. The main sectors that are considered to be drastically hit by climate change on the territory are related to water and water resources management, agriculture and animal husbandry, natural hazards and associated risks management, biodiversity and ecosystems, and human health (Figures 7 and 8).

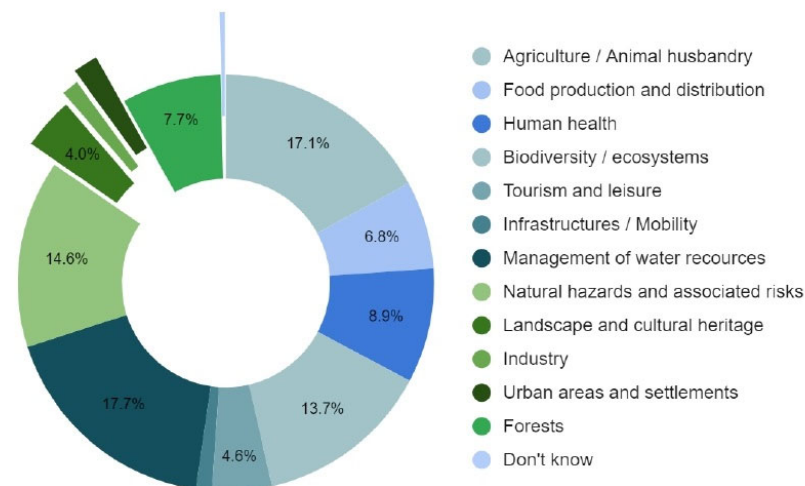


Figure 7. Main findings from some of the key questions from the survey: “What are the main sectors hit by climate change?”.

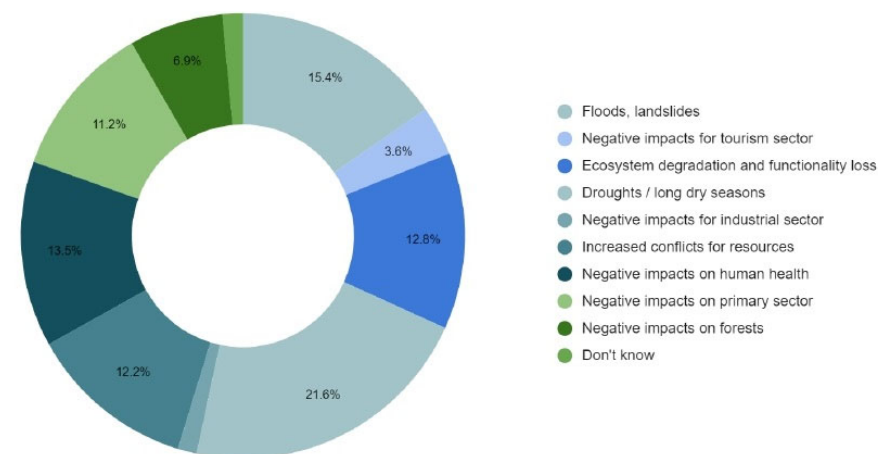


Figure 8. Main findings from some of the key questions from the survey: “What are the main worries regarding climate change?”.

5.2. Adaptation: The Youth Perspective

Starting in early 2023, about 24 local conferences on the topic of climate action promoted by APPA and dedicated to the younger generation took place, with a total of about 300 young people participating, encompassing about 40 associations and/or entities within 18 municipalities (more than 10% of the total number of municipalities of Trentino). About 180 proposals for adaptation measures were produced, covering 13 different key environmental and socio-economic sectors. During the concluding Provincial Youth Climate Conference, the results were synthesised and harmonised in a final document of recommendations that identified around 60 proposed adaptation measures in 10 environmental and socio-economic sectors, all of which have an implementation timeline of approximately five years. The final document was handed over to APPA to inform them further about the future provincial climate strategy. Moreover, it has been presented to provincial deputies and policymakers. This process also created opportunities to build more initiatives of open dialogue on such themes between the young participants and the political representatives

in the period preceding the elections for the provincial government renewal in autumn 2023. The documentation used by this study is available in the Italian language, and more details can be found online [61]. The main topics highlighted during the conferences were related to Agriculture and biodiversity, water resources, soil and landscape, tourism and, only partially, the need for more integrated and cooperative forms of governance.

The proposed measures demonstrate the capacity of younger generations to adopt a broader and holistic perspective on climate challenges and understand the role of correct communication, education, and governance measures on the side of technological innovation and practice. Moreover, they acknowledge that the current economic and incentive mechanisms do not support the transitions to more equitable systems and ask for an approach based on the principle of climate justice. The request to adopt more publicly shared processes to issue laws or regulations on climate adaptation is transversal to all sectors, and it clearly states the need and willingness of youth to be actively and permanently involved in the community. The multidisciplinary perspective of the younger generation on the topic is very significant as it will be beneficial in the transition to a sustainable future. Climate justice and equitable development transversally inform all the measures and strengthen the idea that youth is fully aware that tackling the climate crisis requires changing the socio-economic processes.

Figures 9–11 report a quantitative analysis of the proposed measures.

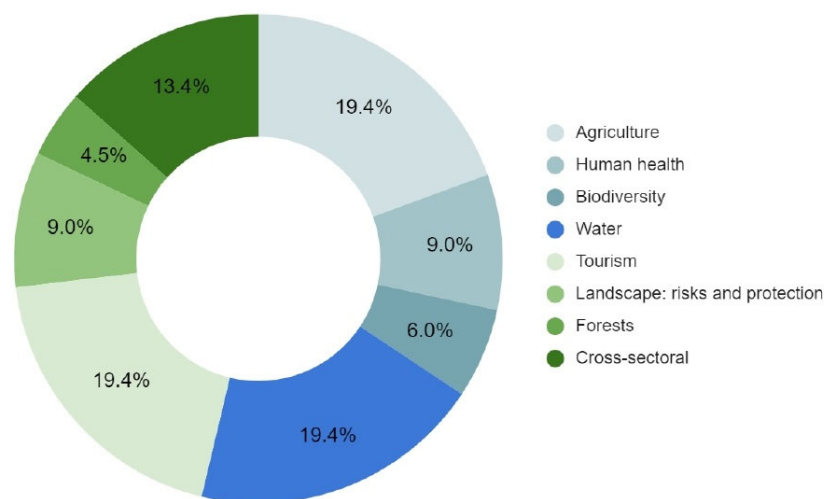


Figure 9. Percentage (%) of adaptation actions divided by sector according to youth conferences on climate.

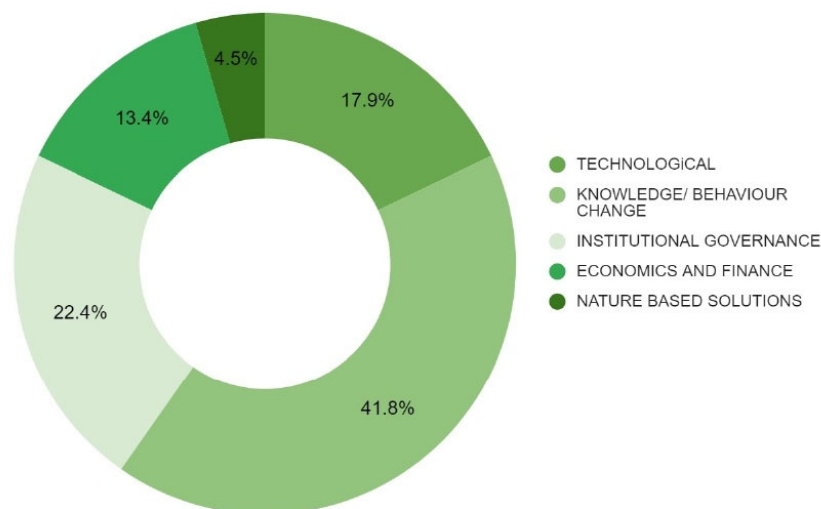


Figure 10. Percentage (%) of actions divided by category according to youth conferences on climate.



Figure 11. Percentage (%) of actions by category for each proposed sector according to youth conferences on climate.

5.3. Adaptation: The Experts' Evaluation

The coordination group consisted of researchers and public officers in a series of workshops aiming to reflect on the priority risks and collect adaptation actions and measures.

Among the main identified risks, “systemic risks” are highlighted. They are of cross-cutting interest and greater significance than the individual areas of discussion, and their effects are realised in combination with ecosystem and socio-economic risks. The main systemic risks investigated are related to water, land use, emerging diseases (both for plants and animals) and increasing conflicts for scarce resources. Such systemic risks are those that combine ecological and socio-economic challenges, potentially creating conditions for wide and severe impacts on the entire landscape and economic structure.

Following the workshops described above, the proposed actions have then been clustered and arranged to define broader measures. Each measure consists of a set of one or more actions, each one representing a step to reach the deployment of the measure itself. Based on this clustering, the researchers have been requested to develop and better describe the contents, targets, and characteristics of the measures. At the end of this first phase, 78 measures attributable to 28 priority risks were collected. Despite a similar number of priority risks selected by each table, the number of proposed measures for each sector is very different.

Table 2 reports the subdivision of risks and measures defined for each sector considered:

Table 2. Risk, number of proposed measures, and number of proposed actions for each sector are considered.

No. of Proposed Actions	No. of Proposed Measures	Associated Risks	Sector
57	13	5	Aquatic ecosystem
45	10	2	Aquaculture
76	10	4	Alpine fauna
45	11	3	Animal husbandry
34	11	4	Apple and other fruits
25	8	3	Forest ecosystem
28	5	3	Human health
43	11	3	Viticulture and wine
353	79	27	Total

The adaptation measures have been further analysed and clustered to identify the possible links, hindering factors or trade-offs among the different sectors. The following Figures 12–15 present a first quantitative analysis of the overall proposed actions to identify the main categories of intervention and the perceived urgency of every action according to the proposed timeline. The proposed actions are divided relatively equally among the different considered sectors, with around 46% of the actions referring to agriculture sectors and the others referring to various natural ecosystems (Figure 12).

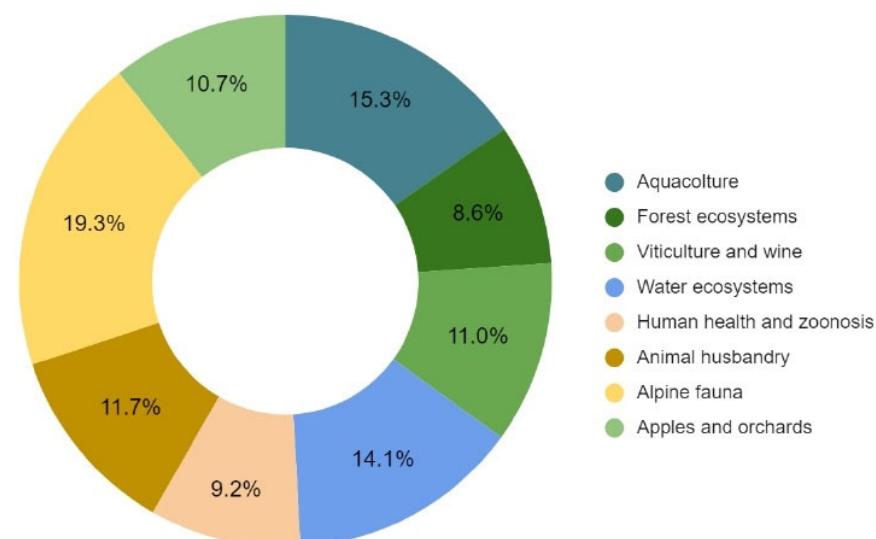


Figure 12. Percentage (%) of adaptation actions divided by sector according to experts' workshop.

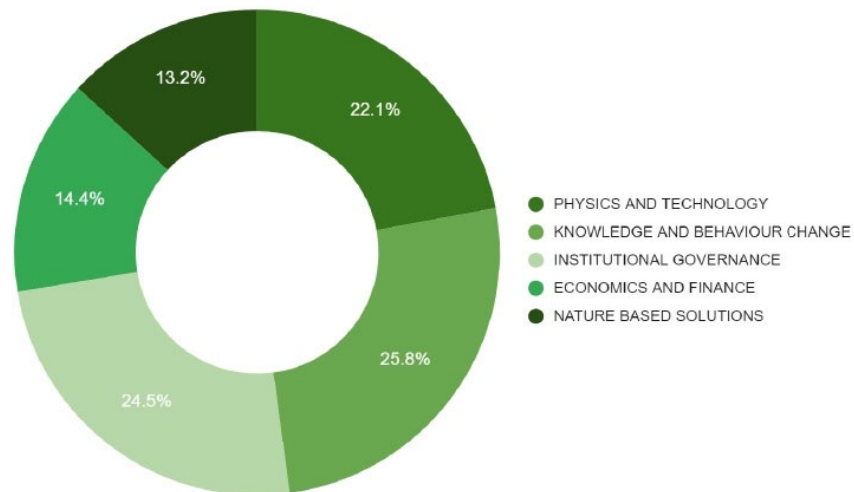


Figure 13. The percentage (%) of adaptation actions is divided by category according to the experts' workshop.



Figure 14. Percentage (%) of adaptation actions divided by category for each specific sector considered according to the experts' workshop.

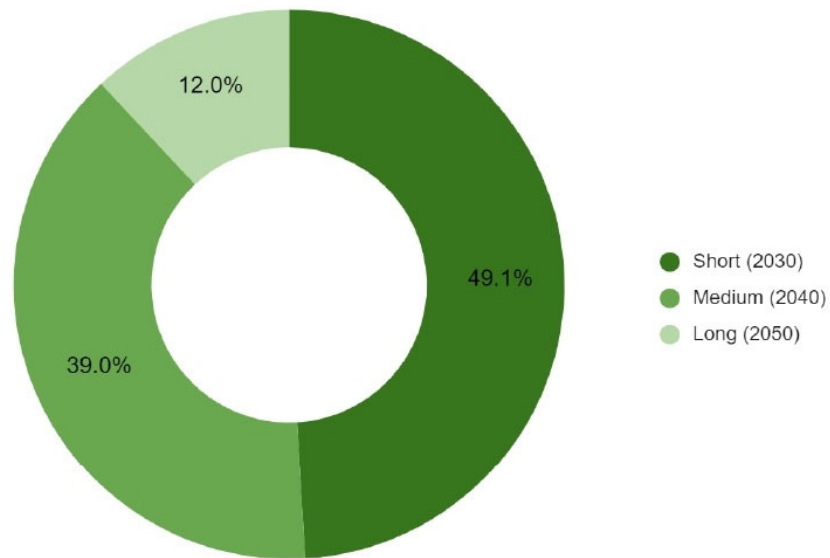


Figure 15. The percentage (%) of adaptation actions is divided by the time of implementation.

Most of the measures refer to knowledge enhancement and research implementation with a focus on climate change adaptation as well as governance and policy scheme improvement. In spite of being proposed by researchers, the number of actions referring to technological or **nature-based solutions** account only for roughly a third of the total (Figures 13 and 14).

The urgency to face climate change through adaptation measures is clearly expressed by the fact that more than 85% of the measures have a short or medium timespan and need to be implemented before 2030 (Figure 15).

A graphical representation of the interlinkages between the different risks, measures, exposed elements, and vulnerabilities was produced for each sector investigated and for each Impact Chain analysed (Figure 16). The choice to use the open-source program “KUMU” allows for the involved team to represent systemic interactions dynamically and interactively.

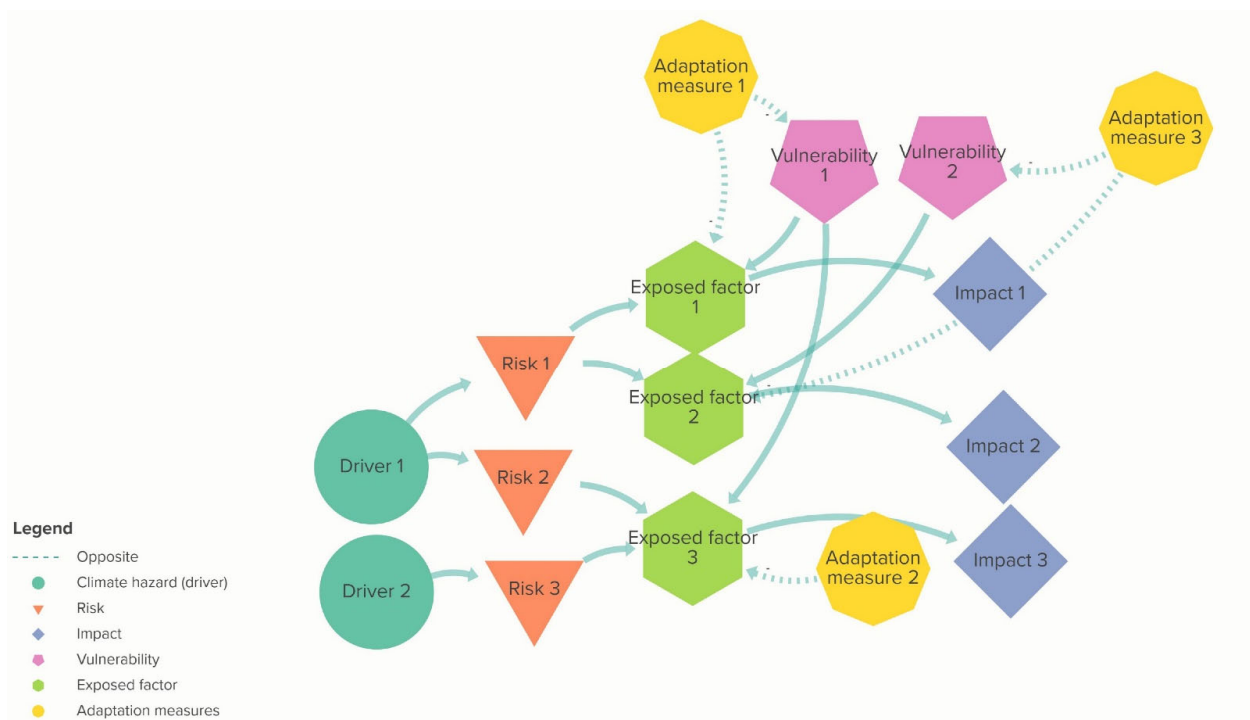


Figure 16. General risk-impacts-measures chain represented through KUMU.

Using KUMU (V2) as a tool to represent Impact Chain models could be beneficial in sharing and spreading awareness on the connections among impacts and stakeholders' roles in facing the climate crisis. This can be helpful when involving non-expert stakeholders and the public and could result in more effective communication and broader participation from their side. This will be especially relevant for the following phase of the working plan, which foresees the involvement of stakeholders to assess, validate, and further specify the content of the measures. This participatory activity will be developed during 2024 to reach the final version of the adaptation measures, which will lead to the adoption and publication of the strategy later in the year.

The proposed measures are described following a template adapted from CMCC and Climate-ADAPT frameworks [52] that have been developed by the workgroup at Fondazione Edmund Mach. The form that the researchers have been asked to fill in contains a technical description of the measure, indications on the perceived priority and feasibility of the measures, possible monitoring indicators, and missing datasets, policies, or resources that could hinder the deployment of the measure. To verify the effectiveness of the proposed measures through time, experts suggested monitoring indicators to refer to. The template used to describe and analyse the adaptation measures is presented in Supplementary Materials.

6. Discussion

The experience and processes presented in this paper, undertaken by the Autonomous Province of Trento, are highly innovative in Italy. Even though other regions have already established their Climate Strategies or Plans, the approach presented here appears to be radically holistic and inherently participatory. It effectively balances and integrates scientific knowledge with societal contributions and citizen perceptions, adopting a truly co-creative approach from the very early stages of its design.

In contrast to other approaches developed in Italy, the inherent co-design ethos adopted from the beginning of the process stands out. In other territories, the preparation of a technical proposal for regional or municipal climate strategies is often entrusted to a single scientific body or consortium, allowing only for an ex-post validation phase open to citizens and stakeholders. This is the case of the Sardegna Region, which received support from the University of Sassari in the first phase and from the University of Cagliari, the Regional Environmental Protection Agency (ARPAS) and the Higher Institute for Environmental Protection and Research (ISPRA) at later stages [62].

This creates significant differences from this study, where continuous assessment of the strategy was performed through various workshops, and it also minimises citizen and stakeholder participation during the ex-post validation of the process. At the same time, in principle, it should ensure better acceptance of the proposed set of adaptation (and mitigation) measures by the local communities and a smoother implementation phase.

Previous experiences in participatory formulation of local and regional strategies and policies (specifically the SPROSS—Provincial Strategy for Sustainable Development and some international cooperative projects co-founded by EIT Climate-KIC [7] like SATURN, HOLISTIC RESILIENCE, RESILIENT REGIONS and MEDCLIV), were fundamental pillars acquired through a learning-by-doing approach. These experiences facilitated the creation of opportunities on which to build and develop a comprehensive pathway towards the Climate Strategy. This involved the collection of data, capacity building of involved staff, and the creation of a network of committed stakeholders. The holistic and participatory aspect has been strengthened by the significant role played by the wide network of stakeholders involved in the early stages of the process, despite the small scale of the territory, ensuring a high and fruitful commitment (evidenced by involving them already in the preliminary definition of the work programme “Trentino Clima 2021–2023” in 2020 [50]).

Despite varying levels of knowledge, expertise, and involvement, the risks linked with climate change have clearly emerged in the discussions and solutions proposed. Some elements appear to be more frequent and important than others due to their intersectionality

or when referring to different temporal scenarios. From a systemic perspective, numerous elements could be leveraged to build a climate strategy; however, in Trentino's case, at least three have clearly emerged as inherently cross-sectorial. They are related to the cross-cutting topics of (1) water, (2) insurance schemes and financial systems, and (3) education, training, and awareness raising. These aspects are of absolute relevance for the territory, and even though their role has already been addressed in some strategy documents, and actions have been undertaken consequently, there is an urgent need to promote further actions.

The adoption of an approach not closely linked to scientific paradigms could be considered reductive. Likewise, an approach that includes co-creation and participation as defining elements could lead to more concrete and easily achievable results. In parallel, it could also be seen as an advantage. Enlarging the number of the actors involved, in fact, facilitates the widening of the interest and, whether possible, supports the acceptance of the proposed strategies and measures as one of the key results for which the process is looking.

7. Conclusions

The pathway of the Autonomous Province of Trento's Climate Strategy design clearly demonstrates the high level of involvement and effort put in by the public authority of this small European region. The regional government is one of the first bodies to sign the Charter of the EU Climate Mission in 2022, showing its commitment to a sustainable future and representing the cornerstone on which the presented process is based. Trentino's experience could be described as one of the few examples (in Italian ground) of the operationalisation of the CLIMATE ADAPT [52] methodology in a truly holistic and participatory approach that involves multi-level stakeholders.

The main challenge encountered by the working group embroiled, is to adapt the tools to respect the peculiarity of the local socio-economic fabric and operate towards a wider representation and participation. One of the key findings is the clear evidence demonstrating how urgent it is to intervene towards a climate strategy. The increased temperature and variation of the precipitation pattern (especially in the winter period) are generating big effects on tourism (with reduced snowfalls and less availability of water), on agriculture (reduction of irrigation water, problems with crops related to anticipated phenology and increasing presence of pest) and health effects connected with changed biodiversity, affecting both human and fauna, directly related to the risk of an increasing vulnerability to pathogens.

Those are aspects directly related to climate emergency that should also be interfered with societal elements, such as migration, ageing, economic dynamics and more. What has already happened, and potentially will occur in Trentino in the next years, is the progression of a drastic transformation of the actual productive and living paradigm. In order to pursue the objectives of the Climate Strategy, a few elements should be considered relevant. Multiple risks that could affect the different sectors can be analysed using an interdisciplinary approach. This creates the opportunity to learn and innovate through applied scientific research undertaken in a defined territory. That is enhanced by the strong participation of sectoral experts and stakeholders at many levels and the factual participation of the youngest group of citizens, thus favouring a multi-level approach encompassing inter-generational participation. A similar approach could become consolidated within several public institutions and be included in the governance tools, hopefully as part of a transnational normative framework.

Exchange, capitalisation, and implementation are the twofold elements that can help Trentino deploy its climate strategy. Leveraging on youth involvement and research projects is another potential future-proofed investment that works both for the Trentino example and other territories as well.

The potential solutions should be part of a process of trade-off individuation and negotiation. The ambition and needs of different economic sectors and citizens call for a balanced and wise planning of the use of natural resources, which should also relate to the realisation of specific structures and infrastructures to be developed locally. The

co-creative and participatory nature of the process adopted since its very beginning should also help in the phase of actual implementation and operationalisation of the climate strategy, ensuring greater acceptance by the local communities of the adaptation measures and the transformations needed. The emergence of conflicts related to the governance of activities and access to resources cannot be ruled out a priori, but the adoption of a precautionary approach shared by the actors involved could reduce their impacts.

The results of this study's bottom-up approach will form a new proposal for the normative and planning frameworks of the Autonomous Province of Trento. Its practical implications will derive from addressing the actual and future activities leveraging the planning, economic and educational sectors, both at the public and private levels. It has been learned that qualitative and quantitative approaches to climate risk assessments, as well as experts' evaluation and stakeholder co-design for adaptation measures definition, often lead to very similar results (sometimes rather unexpectedly). Following the indication of the climate policy adopted, for example, from the European Commission, a further process of normative adoption and realisation can clearly help in a wider application and a successful transformative process, as anticipated earlier.

The limitations derive from the peculiarity of each spatial level of reference (related to dimension, topography, and socio-economic fabric) and the fact that the process is time- and (human) resources-demanding (developing processes take at least 2–3 years), while the implementation of proper and systemic adaptation actions is urgently needed. These aspects could represent a clear barrier to properly implementing the above-presented process. The added value of greater awareness and acceptance, and especially ownership of the solution, justifies the adoption of a journey like the one undertaken by Trentino and could be used as a reference for similar replication in other territories within the framework of international projects or frameworks.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su16104198/s1>, File S1: Scheda Tecnica Adattamento.

Author Contributions: Conceptualisation, A.G., A.N. and L.L. (Lavinia Laiti); methodology, A.G., L.L. (Lavinia Laiti) and R.B.; validation, A.G., A.B. and L.L. (Lavinia Laiti); formal analysis, A.G., L.L. (Lavinia Laiti) and R.B.; investigation, A.G., A.B. and L.L. (Linda Lugli); resources, A.G., L.L. (Linda Lugli) and A.N.; data curation, A.G., A.B., L.L. (Lavinia Laiti) and L.L. (Linda Lugli); writing—original draft preparation, A.N., A.G., A.B., L.L. (Lavinia Laiti) and L.L. (Linda Lugli); writing—review and editing, A.N., A.G., A.B., L.L. (Lavinia Laiti) and L.L. (Linda Lugli); visualisation, A.B.; supervision, A.G., L.L. (Lavinia Laiti) and R.B.; project administration, L.L. (Lavinia Laiti) and R.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Acknowledgments: Part of the activities has been co-supported by the Autonomous Province of Trento—Agency for Environment Protection (APPA) under the Trentino Clima 2021–2023 activities for the years 2021–2023. The authors are grateful to all the experts within public bodies, research institutions, and economic sectors who contributed to the participatory activities.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Wilson, E. Adapting to climate change at the local level: The spatial planning response. *Local Environ.* **2006**, *11*, 609–625. [[CrossRef](#)]
2. Fraundorfer, M. The role of cities in shaping transnational law in climate governance. *Glob. Policy* **2017**, *8*, 23–31. [[CrossRef](#)]
3. Hakelberg, L. Governance by diffusion: Transnational municipal networks and the spread of local climate strategies in Europe. *Glob. Environ. Politics* **2014**, *14*, 107–129. [[CrossRef](#)]
4. FAO. FAO Strategy on Climate Change 2022–2031. 2022. Rome. Available online: <https://www.fao.org/3/cc2274en/cc2274en.pdf> (accessed on 23 November 2023).

5. Kondrup, C.; Mercogliano, P.; Bosello, F.; Mysiak, J.; Scoccimarro, E.; Rizzo, A.; Ebrey, R.; de Ruiter, M.; Jeuken, A.; Watkiss, P. *Climate Adaptation Modelling*; Springer Nature: Berlin/Heidelberg, Germany, 2022; p. 238. [CrossRef]
6. Copernicus, Europe's Eyes on Earth. Available online: <https://climate.copernicus.eu/copernicus-2023-hottest-year-record#:~:text=Samantha%20Burgess,%20Deputy%20Director%20of,than%20the%20pre-industrial%20period> (accessed on 20 December 2023).
7. EIT Climate-KIC. Available online: <https://www.climate-kic.org/> (accessed on 20 December 2023).
8. Regional Adaptation Support Tool (RAST) of Mission Clima European Union. Available online: <https://climate-adapt.eea.europa.eu/en/mission/knowledge-and-data/regional-adaptation-support-tool> (accessed on 20 December 2023).
9. Zhou, K.; Wang, S.; Feng, Y. How Is Spatial Planning Adapting to Climate Change? A Textual Analysis Based on the Territorial and Spatial Plans of 368 Chinese Cities. *Land* **2023**, *12*, 1993. [CrossRef]
10. Dalal-Clayton, B.; Bass, S. *Sustainable Development Strategies*; Taylor & Francis Ltd.: London, UK, 2002. [CrossRef]
11. Biesbroek, G.R.; Swart, R.J.; Carter, T.R.; Cowan, C.; Henrichs, T.; Mela, H.; Morcecroft, M.D.; Rey, D. Europe adapts to climate change: Comparing national adaptation strategies. *Glob. Environ. Change* **2010**, *20*, 440–450. [CrossRef]
12. EEA, 2019: Climate-Change-Adaptation-in-the-Agriculture-Sector-in-Europe. Available online: <https://euroseeds.eu/app/uploads/2019/09/Climate-change-adaptation-in-the-agriculture-sector-in-Europe.pdf> (accessed on 25 January 2024).
13. Urwin, K.; Jordan, A. Does public policy support or undermine climate change adaptation? Exploring policy interplay across different scales of governance. *Glob. Environ. Change* **2008**, *18*, 180–191. [CrossRef]
14. Preston, B.L.; Westaway, R.M.; Yuen, E.J. Climate adaptation planning in practice: An evaluation of adaptation plans from three developed nations. *Mitig. Adapt. Strateg. Glob. Change* **2011**, *16*, 407–438. [CrossRef]
15. Brooks, N.; Anderson, S.; Ayers, J.; Burton, I.; Tellam, I. *Tracking Adaptation and Measuring Development*; International Institute for Environment and Development: London, UK, 2011; ISBN 978-1-84369-834-0.
16. Smit, B.; Burton, I.; Klein, R.J.; Wandel, J. An Anatomy of Adaptation to Climate Change and Variability. *Clim. Change* **2000**, *45*, 223–251. [CrossRef]
17. Department for Environment, Rural Affairs. *The UK Government Sustainable Development Strategy*; The Stationery Office: London, UK, 2005; Volume 6467.
18. Kern, K.; Alber, G. Governing climate change in cities: Modes of urban climate governance in multi-level systems. In Proceedings of the International Conference on Competitive Cities and Climate Change, Milan, Italy, 9–10 October 2009; pp. 171–196.
19. Allman, L.; Fleming, P.; Wallace, A. The progress of English and Welsh local authorities in addressing climate change. *Local Environ.* **2004**, *9*, 271–283. [CrossRef]
20. Davies, A.R. Local action for climate change: Transnational networks and the Irish experience. *Local Environ.* **2005**, *10*, 21–40. [CrossRef]
21. Vileniske, I.G. Influence of built heritage on sustainable development of landscape. *Landsc. Res.* **2008**, *33*, 425–437. [CrossRef]
22. Council of Europe. *European Landscape Convention*; Florence, European Treaty Series; Council of Europe: Strasbourg, France, 2000.
23. Antrop, M. Sustainable landscapes: Contradiction, fiction or utopia? *Landsc. Urban Plan.* **2006**, *75*, 187–197. [CrossRef]
24. Matthews, R.; Selman, P. Landscape as a focus for integrating human and environmental processes. *J. Agric. Econ.* **2006**, *57*, 199–212. [CrossRef]
25. Moore, K. The aesthetics of sustainable landscape infrastructure: Landscape and infrastructures for society. In Proceedings of the Ninth Meeting of the Workshops of the Council of Europe, Cordoba, Spain, 15–16 April 2010; pp. 108–116.
26. Nikologianni, A. The Role of Low Carbon, Spatial Quality and Drawings in Landscape-Based Regional Strategies. Ph.D. Thesis, Birmingham City University, Birmingham, UK, 2018.
27. Mallick, S.K. Prediction-Adaptation-Resilience (PAR) approach-A new pathway towards future resilience and sustainable development of urban landscape. *Geogr. Sustain.* **2021**, *2*, 127–133. [CrossRef]
28. Xia, L.; Cheng, W. Sustainable development strategy of rural built-up landscapes in Northeast China based on ANP approach. *Energy Procedia* **2019**, *157*, 844–850. [CrossRef]
29. McNerney, D.; Lempert, R.; Keller, K. What are robust strategies in the face of uncertain climate threshold responses? Robust climate strategies. *Clim. Change* **2012**, *112*, 547–568. [CrossRef]
30. Girard, F.L. Toward a smart sustainable development of port cities/areas: The role of the “Historic Urban Landscape” approach. *Sustainability* **2013**, *5*, 4329–4348. [CrossRef]
31. Knickel, K.; Brunori, G. Exploring the ‘research-practice gap’ in agricultural and rural development: Lessons from the EU experience. *Sociol. Rural.* **2017**, *57*, 272–292. [CrossRef]
32. Grigorieva, E.; Livenets, A.; Stelmakh, E. Adaptation of Agriculture to Climate Change: A Scoping Review. *Climate* **2023**, *11*, 202. [CrossRef]
33. Nilsson, J.E.; Liess, A.; Ehde, P.M.; Weisner, S.E. Mature wetland ecosystems remove nitrogen equally well regardless of initial planting. *Sci. Total Environ.* **2020**, *716*, 137002. [CrossRef]
34. Caravella, S.; Crespi, F. Unfolding heterogeneity: The different policy drivers of different eco-innovation modes. *Environ. Sci. Policy* **2020**, *114*, 182–193. [CrossRef]
35. Wang, H.; Zhao, Y.; Gao, X.; Gao, B. Collaborative decision-making for urban regeneration: A literature review and bibliometric analysis. *Land Use Policy* **2021**, *107*, 105479. [CrossRef]
36. Briner, S.; Elkin, C.; Huber, R. Evaluating the relative impact of climate and economic changes on forest and agricultural ecosystem services in mountain regions. *J. Environ. Manag.* **2013**, *129*, 414–422. [CrossRef]

37. Tasser, E.; Leitinger, G.; Tappeiner, U. Climate change versus land-use change—What affects the mountain landscapes more? *Land Use Policy* **2017**, *60*, 60–72. [CrossRef]
38. Delay, E.; Piou, C.; Quénol, H. The mountain environment, a driver for adaptation to climate change. *Land Use Policy* **2015**, *48*, 51–62. [CrossRef]
39. Grüneis, H.; Penker, M.; Höferl, K.M. The full spectrum of climate change adaptation: Testing an analytical framework in Tyrolean mountain agriculture (Austria). *SpringerPlus* **2016**, *5*, 1848. [CrossRef] [PubMed]
40. Behringer, J.; Buerki, R.; Fuhrer, J. Participatory integrated assessment of adaptation to climate change in Alpine tourism and mountain agriculture. *Integr. Assess.* **2000**, *1*, 331–338. [CrossRef]
41. Cattivelli, V. Climate Adaptation Strategies and Associated Governance Structures in Mountain Areas. The Case of the Alpine Regions. *Sustainability* **2021**, *13*, 2810. [CrossRef]
42. Cattivelli, V. Macro-Regional Strategies, Climate Policies and Regional Climatic Governance in the Alps. *Climate* **2023**, *11*, 37. [CrossRef]
43. ISPAT—Istituto di Statistica della Provincia di Trento. Available online: http://www.statistica.provincia.tn.it/binary/pat_statistica_new/popolazione/SintesiPopolazioneTrentinoPerEt_1_01_2023Provvisori.1684390584.pdf (accessed on 25 January 2024).
44. European Environmental Agency, European Climate Risk Assessment (2024). Available online: https://www.eea.europa.eu/en/newsroom/news/europe-is-not-prepared-for?utm_medium=email&_hsmi=84469544&_hsenc=p2ANqtz--1jmp2t-4tNVp8yU8aOyNDq59bwXdnILqbd_v6TKpgpH4DRRjNGtsKkMfExmk1nu9CIJ48LJilPrCQ-BF4QcPq3o4J9ysrv5fmxDOSc19SRtr7Os&utm_content=84469544&utm_source=hs_email (accessed on 20 December 2023).
45. APPA. *Report on State of Climate in Trentino (In Preparation, 2024)*; APPA: Trento, Italy, 2024.
46. Linee Guida per le Strategie Regionali di Adattamenti ai Cambiamenti Climatici 2019. Available online: <https://www.bing.com/ck/a?!&p=6e9bae480e9407c7JmltdHM9MTcxNTI5OTIwMCZpZ3VpZD0xNmQyZTkYYS01Y2M2LTY1YzgtMzczYi1mZDUwNWRjNzY0MmQmaW5zaWQ9NTE3Mg&ptn=3&ver=2&hsh=3&fclid=16d2e92a-5cc6-65c8-373b-fd505dc7642d&u=a1aHR0cHM6Ly9wb2xpdGljaGVjb2VzaW9uZS5nb3Zlcm5vLml0L2l1ZGhLzI4NjcvbGluZWUtZ3VpZGEtc3RyYXRlZ2l1LXJlZ2lvbmFsaS1hZGF0dGFtZW50by1jYW1iaWFtZW50aS1jbGltYXRpY2kucGRm&ntb=1> (accessed on 20 December 2023).
47. Master ADAPT—MAInStreaming Experiences at Regional and Local Level for ADAPTation to Climate Change. Available online: <https://masteradapt.eu/> (accessed on 20 December 2023).
48. Ministero dell’Ambiente e della Sicurezza Energetica-Progetto Creiamo PA. Available online: <https://www.mase.gov.it/pagina/iniziative-e-progetti-supporto-dell-attuazione-della-snsvs-progetto-creiamo-pa> (accessed on 20 December 2023).
49. The Alpine Convention. Available online: <https://www.alpconv.org/en/home/> (accessed on 20 December 2023).
50. Trentino Clima 2021–2023. Available online: <https://www.appa.provincia.tn.it/Documenti-e-dati/Documenti-tecnici-di-supporto/Trentino-Clima-2021-2023> (accessed on 20 December 2023).
51. Sviluppo Sostenibile in Trentino—Agenda 2030. Available online: <https://agenda2030.provincia.tn.it/Trentino-2030/Strategia-provinciale-SproSS> (accessed on 20 December 2023).
52. Climate ADAPT: Sharing Adaptation Knowledge for a Climate-Resilient Europe. Available online: <https://climate-adapt.eea.europa.eu/en/knowledge/tools/adaptation-support-tool> (accessed on 20 December 2023).
53. Climate ADAPT—The Adaptation Support Tool. Available online: <https://climate-adapt.eea.europa.eu> (accessed on 20 December 2023).
54. Regione Piemonte—La Strategia Regionale sui Cambiamenti Climatici (SRCC). Available online: <https://www.regione.piemonte.it/web/temi/strategia-sviluppo-sostenibile/strategia-regionale-sui-cambiamenti-climatici-srcc> (accessed on 20 December 2023).
55. Zebisch, M.; Schneiderbauer, S.; Rennen, K.; Below, T.; Brossmann, M.; Ederer, W.; Schwan, S. Risk Supplement to the Vulnerability Sourcebook. In *Guidance on How to Apply the Vulnerability Sourcebook’s Approach with the New IPCC AR5 Concept of Climate Risk*; Deutsche Gesellschaft für Internationale Zusammenarbeit: Bonn, Germany, 2017.
56. Piano Energetico Ambientale Provinciale 2021–2030. Available online: <https://www.provincia.tn.it/Documenti-e-dati/Documenti-di-programmazione/Piano-Energetico-Ambientale-Provinciale-2021-2030> (accessed on 20 December 2023).
57. APPA Agenzia Provinciale per la Protezione Dell’ambiente. Available online: <https://www.appa.provincia.tn.it/News/APPa-informa-Newsletter-periodica/Cambiamenti-climatici-in-Trentino.-Quanto-ne-sai-i-risultati-dell-indagine> (accessed on 20 December 2023).
58. Zebisch, M.; Terzi, S.; Pittore, M.; Renner, K.; Schneiderbauer, S. Climate Impact Chains—A Conceptual Modelling Approach for Climate Risk Assessment in the Context of Adaptation Planning. In *Climate Adaptation Modelling*; Kondrup, C., Mercogliano, P., Bosello, F., Mysiak, J., Scoccimarro, E., Rizzo, A., Ebrey, R., de Ruiter, M., Jeuken, A., Watkiss, P., Eds.; Springer: Cham, Switzerland, 2022. [CrossRef]
59. Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici. Climate Risk Reports. Available online: <https://www.cmcc.it/research/publications/climate-risk-reports> (accessed on 22 April 2024).
60. Brophy, H.; Olson, J.; Paul, P. Eco-anxiety in youth: An integrative literature review. *Int. J. Ment. Health Nurs.* **2023**, *32*, 633–661. [CrossRef]

61. Sistema Nazionale per la Protezione Dell'ambiente. Available online: <https://www.snpambiente.it/2023/> (accessed on 20 December 2023).
62. Strategia Regionale di Adattamento ai Cambiamenti Climatici, Regione Sardegna Adottata dalla Giunta Regionale con la Deliberazione n. 6/50 del 5 Febbraio 2019. Available online: <https://delibere.regione.sardegna.it/protected/45523/0/def/ref/DBR45368/> (accessed on 20 December 2023).

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.