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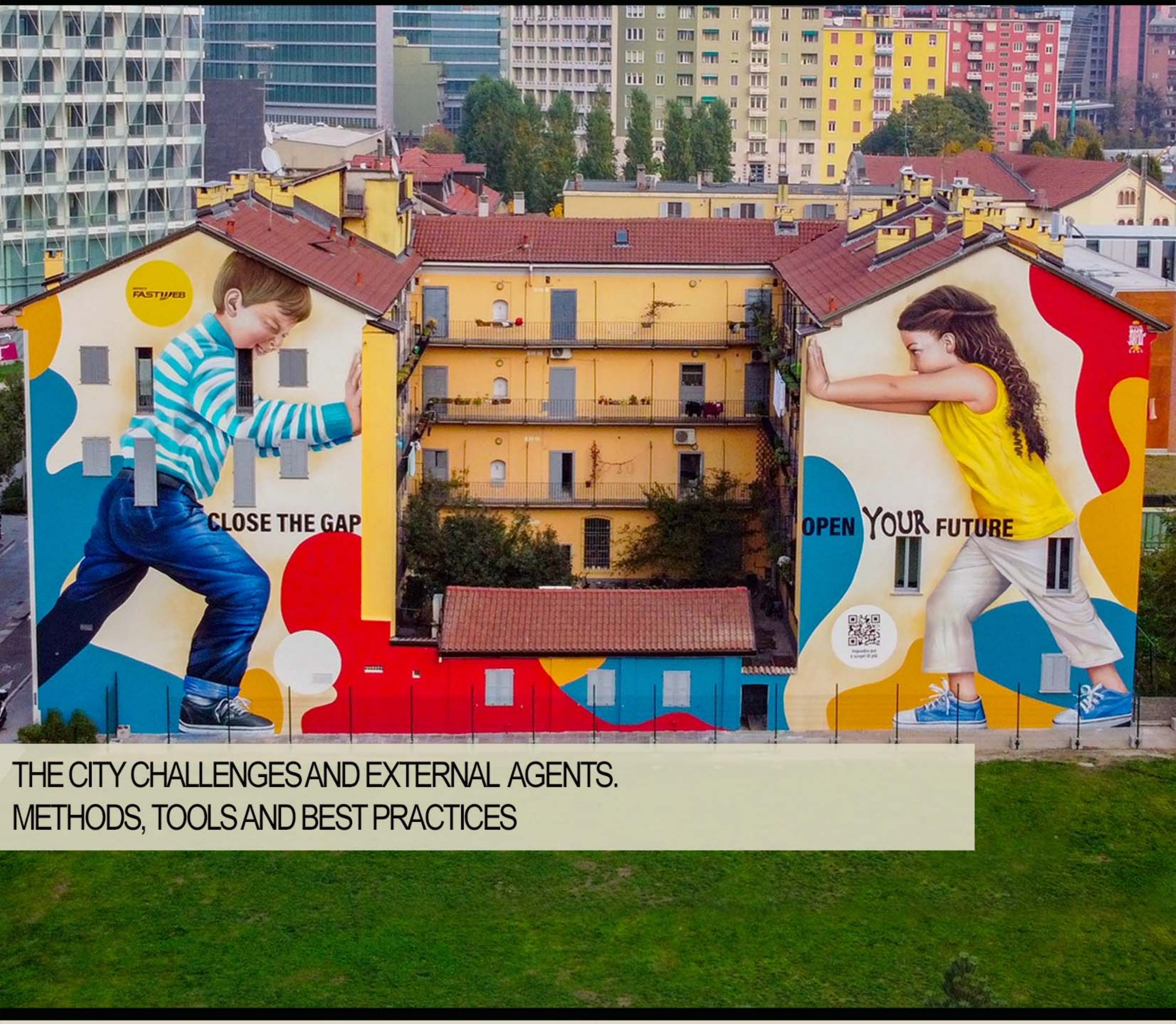

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Mountain tourism facing climate change. Assessing risks and opportunities in the Italian Alps

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Abstract

The Alps are an interesting case for studying the relationship between tourism and climate change. Despite a growing number of studies, the impacts of climate change on the tourism sector remain uncertain, when the regional and local scale or seasonality are considered. This article presents a risk methodology to assess the spatial distribution of the main challenges and opportunities for winter and summer tourism due to climate change at the sub-regional level on a 2021-2050 scenario. This methodology has been tested on an Italian Alpine area, which consists of very different landscapes from plain to high mountains. The results show that high-altitude municipalities will face the stronger risks for winter touristic activities, due to reduced snow cover duration, but also opportunities to attract in summer tourists escaping from the hotter temperatures of the plain. At the same time, climate change could have secondary negative effects in these areas, as it will increase the frequency and the magnitude of extreme events. The results show that impacts of CC cannot be generalised, even in a limited area; same hazards due to changes in temperature and precipitation patterns can generate very different risk scores, because of local conditions related to exposure and vulnerability factors.

Keywords

Climate change; European Alps; Tourism; Risk; Seasonality; Vulnerability.

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1. Introduction

The academic debate on the relationship between tourism and climate change has grown dramatically in the last twenty years and has become a distinct branch of knowledge (Ali, 2016; Becken, 2013). The carbon footprint of the tourism sector accounts for about 8% of global greenhouse gas emissions (Lenzen et al., 2018). At the same time, tourism is one of the human activities which have been and will be more threatened by climate change (Mora et al., 2018), either because of its direct effects such as variations in temperatures and precipitations (Wilkins et al., 2018), but also due to secondary effects such as the increase in frequency and extent of natural disasters (Rosselló et al., 2020).

The European Alps are an interesting case study within the relationship between tourism and climate change. In fact, the Alps have been identified as one of the most vulnerable areas to impacts of climate change in Europe (Hock et al., 2019). In recent decades, the impacts of observed climate change have been of different types and intensity (IPCC, 2022), and a significant further intensification of climate change is predicted by the major climate models for the coming decades in terms of increased temperatures, intensity and variation of seasonal precipitation, elevation of minimum snowfall and ice retreat (Ballarin-Denti et al., 2015). These trends are foreseen to have relevant impacts on tourism, which plays a crucial role in the economy of this region (Agrawala, et al., 2007).

Despite a growing number of studies in the field, the impacts of climate change to the Alpine tourism sector remain uncertain, especially when at the regional and at the local scale (Pütz et al., 2011; Steiger et al., 2020) when seasonality is taken into consideration (Serquet & Rebetez, 2011). In addition, the Alpine region includes areas that are extremely heterogeneous – even over a very short distance – in terms of elevation, landscape, socio-economic and environmental systems, etc. Therefore, the touristic attractivity of these areas can be affected by climate change to a very different extent, especially when distinguishing between winter and summer tourism (Pröbstl-Haider et al., 2015).

For these reasons, this article presents a spatial risk methodology to assess the main challenges for winter and summer tourism to climate change at the sub-regional level. This methodology used as a case study the so-called Homogeneous Zone of Pinerolo (HZP), which is characterized by very different landscapes, from flatland to high mountains. The results achieved as well as the methodology here implemented could be used as a spatial decision support system for public administration and local stakeholders to identify where winter and summer tourism is most threatened (or favoured), and which adaptation measures need to be implemented to face these expected risks.

Section 2 describes the literature state-of-the-art in relation to the impacts of climate change on the Alpine tourism. Section 3 introduced the case study, while Section 4 focuses on the analytical methods adopted to estimate the present and future climate, by explaining in depth which climate indicators have been used to determine not only the observed anomalies, but also the future trends (2021-2050). Section 5 presents and discusses the main results and, finally, a concluding session explores the implications and possible uses of the proposed research in terms of climate change adaptation policies for tourism.

2. Literature review

2.1 Climate trends and expected hazards in the Alps

The European Alps have experienced significant damages from climate change in the last decades, and further intensifying of these trends is foreseen by regional climate projections by the end of this century (Gobiet & Kotlarski, 2020). During the 20th century, the Alps registered increases in minimum temperatures of up to 2°C, and a more modest increase in maximum temperatures. This trend was particularly strong after the mid 1970s, and since mid 1980s warming observed in the Alps has been about three times higher than the global average, particularly in summer and spring seasons (Auer et al., 2007; Beniston, 2005; Ceppi et al., 2012). In a comprehensive review of climate projections for the Alps, Gobiet et al. (2014) explained how a warming of 1.5°C is expected in the first half of the 21st century, compared to the reference period 1961–1990. This trend is supposed to increase up to 3.3°C in the second half. With regards to precipitations, changes have been subject to larger uncertainties and varied greatly from region to region. In relation to the future, the annual precipitation are expected to remain rather constant, while winter precipitations are expected to increase. The most negative consequences on precipitation pattern are expected within summer, but changes are possible due to the model uncertainty range. Nevertheless, extreme precipitation events are expected to intensify in all seasons (Gobiet et al., 2014). It is also important to highlight that long-time range projected changes considerably depend on the greenhouse-gas scenario under consideration. Specifically, the most prominent changes are associated to the worst Representative Concentration Pathway (IPCC, 2014a), the RCP8.5 scenario, by the end of the 21st century, while in relation to the mid-century these impacts are expected to vary slightly depending on the selected scenario (i.e., RCP4.5 or RCP8.5) (Gobiet & Kotlarski, 2020). Looking at the snowfall phenomenon, a reduction of 36% in winter it is expected, with a complete disappearance below 500 metres of altitude (EEA, 2009). On the contrary, extreme events are expected to intensify, particularly in the fall season (Rajczak et al., 2013).

These past and future climatic changes in temperatures and precipitations directly affected the comfort conditions for tourism, but they also have serious side effects. In fact, together with accelerated retreat in glacier cover and permafrost, these phenomena can lead to an increase of the frequency and the magnitude of natural hazards such as landslides, rock falls, debris flows, avalanches and floods (Keiler et al., 2010; Schindelegger & Kanonier, 2019). Table 1 summarises these hazards and their potential impacts on infrastructures, socio-economic and cultural activities related to the tourism in mountain regions.

Natural hazard	Description	Potential impact level	Sources
Desertification	Higher aridity of agricultural, forestry and pastoral areas with consequent rise in erosion and loss of organic matter in forest areas as a result of increased fire risk in connection with drought-related events.	Low	Corrado et al., eds., 2014 Matasci and Altamirano - Cabrera, 2010 Probst et al., 2013
Ecosystem changes (land and aquifer)	Changes in the phenological cycle and inland water and ecosystem transition (i.e. shift) due to habitat and soil mutations.	High	Beniston, 2012 Cannone et al. 2008 Cantonati et al., 2006 Ianni et al., 2015 Mourier et al., 2010 Revernmann et al., 2012 Wieser et al., 2008
Forest fires	Expected increase in the danger of forest fires throughout the year, mainly in the spring season.	Medium	Dupire et al., 2019 Moriondo et al., 2006 Moser et al., 2010 Schumacher and Bugmann, 2006 Wastl et al., 2012
Hydro-geological and hydraulic instability	Variation in seasonality and magnitude of phenomena associated with snow dynamics, instability of rock complexes, debris flows and surface landslides.	High	Ellena et al., 2020 Palladino et al., 2018 Probst et al., 2013 Prudent-Richard et al., 2008 Winkler and Reichl, 2014
Water scarcity	Decrease in the availability and quality of water resources related to the reduction of precipitation in winter and summer seasons.	Medium-high	Brunner et al., 2019 Hohenwallner et al., 2011 Klug, 2011 Mastrotheodoros et al., 2020 Zampieri et al., 2016

Tab.1 Predicted natural hazards due to climate change and their potential impact levels on tourism

2.2 Impacts of climate change on winter and summer tourism in the Alps

The Alpine regions are visited each year by 60-80 million people (four to six times the local population), accounting for 386 million commercial overnight stays (14.4% of the European total) of which 43.3% of the are concentrated in winter (from November 1st to April 30th) 126 million euros relates to the non-commercial stays. In the region, tourism generates an annual turnover close to 50 billion euros, and it provides 10-12% of employment (Agrawala et al., 2007; Future Mountain International, 2016).

As briefly explained before, tourism in the Alps is mainly dependent on natural resources and climate, therefore it is particularly vulnerable to climate change both in winter and in summer seasons, with impacts which diverge substantially (Balbi, 2012).

With regards to ski tourism, the Alps account for 37% of ski resorts worldwide and 80% of major resorts (i.e., 1 million skier visits per winter season). In fact, the region is the biggest ski destination in the world, capturing 43% of skier visits in the 2018/19 ski season (Vanat, 2020). Since snow is the key attraction in the Alps (Bausch & Gartner, 2020; Unbehaun et al., 2008), the evolution of natural snow conditions due to climate change is considered as a major threat (Elsasser & Bürki, 2002; Spandre et al., 2019). A recent review by Steiger et al. (2019) has comprehensively highlighted the main consequences resulting from these impacts. These were summarised as a decreased reliability of slopes dependent on natural snow, an increased snowmaking requirement, a shorter and more variable ski seasons, a contraction in the number of operational ski areas, altered competitiveness between and within regional ski markets, and related implications for ski tourism employment and holiday property values.

The first studies on the impact of climate change on winter tourism in the Alps appeared in the 1990s, mainly because of three consecutive snow-deficient winters at the end of the 1980s, which revealed the dependence of the Alpine tourism industry on snow cover (Koenig & Abegg, 1997).

In the early 2000s, a few studies tried to quantify the snow reliability of ski resorts based on the "100 days" rule, first suggested by Witmer (1986), which states that to successfully operate a ski area, natural snow cover should exceed 30 cm at least 100 days per season. The snow reliability line - i.e., the elevation above which these conditions are met - is supposed to rise by 150 m per each +1°C warming. Abegg et al. (2007) calculated that under present climate conditions, 91% of the current 666 Alpine ski areas can be considered as naturally snow-reliable. Under future climate change this percentage could drop to 75% with a +1°C warming, to 61% with a +2°C warming and to 30% with a +4°C warming. In other words, global warming could determine a process of concentration of ski and snow activities in areas at higher altitude with reliable snow cover (Elsasser & Messerli, 2001). Much less attention has been paid so far to the impacts of climate change on summer tourism in the Alps. In this case, the expected impacts seem less critical or might even be positive in some cases. According to Pröbstl-Haider et al. (2015), the Alps will attract more tourists in the summer, because this area is characterized by a more comfortable range of temperatures compared to lowlands during summer. On the other hand, the Alps will become more appealing for activities such as mountaineering, climbing, hiking and lake tourism thanks to additional days with sunshine.

Serquet & Rebetez (2011) analysed the relationship between temperature and overnight stays in 40 Alpine resorts, finding significant correlations between the number of nights spent in mountain resorts and hot temperatures at lower elevations (where most domestic tourists live). This correlation is stronger for Alpine resorts nearest to major cities. These results suggest that if climate change increases heat waves in frequency and intensity, domestic tourists will go to mountain resorts more frequently or for longer periods.

Conversely, negative effects could derive from natural hazards (e.g., landslides) related to the loss of permafrost, melting glaciers and heavy rain events, which could lead to dangerous situations for summer activities (such as mountaineering, etc.) and damage the infrastructures that ensure accessibility to Alpine areas (Pröbstl-Haider et al., 2015).

Overall, the positive economic effects of climate change on summer tourism will not necessarily offset the negative economic effects on winter tourism. For instance, Müller and Weber (2008) estimated the effects of climate change on tourism revenues in the Swiss region of Bernese Oberland in 2030.
Results showed that the increase of the revenues for the summer season (7%) would not be sufficient to avoid a comprehensive loss of about 7% (4% in case of implementation of adaptation measures) per year.

3. Aims and case study

3.1 Aims

Climate change impacts are related to changes of the average patterns of temperature and precipitation, but also to changes in frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events (IPCC, 2012).
Therefore, these impacts vary according to factors such as elevation, geomorphological features, socioeconomic structures, etc. As Elsasser and Messerli (2001) state, in relation to tourism these impacts can induce a spatial division into "winners" (positively affected) and "losers" areas (negatively affected). Notwithstanding, the literature reviewed in section 2.2 shows how the debate has mainly been focused on analysing climate change impacts on tourism at the level of the whole Alpine region, or at specific sub-levels such as supra-national (e.g., the Eastern Alps), national (e.g., the Swiss Alps), or regional (e.g., the Bernese Oberland). Much less attention was paid to examining how risks for tourism due to climate change are distributed at the intra-regional level, i.e., between the different municipalities included in a specific Alpine region. This is a key driver in the elaboration of strategies for climate change adaptation, which are usually defined at sub-regional level (Agrawala et al., 2007) and implemented at the local level (Bonzanigo et al., 2016).
This paper aims to propose a reproducible methodology for analysing how climate change risks for tourism can differ through locations within a regional case study, in order to identify where adaptation measures need to be prioritize (Oppenheimer et al., 2014; Schindelegger & Kanonier, 2019).

3.2 Selection of the case study

To test the proposed methodology (illustrated in section 4) a case study was selected in the Western Italian Alps. It is the Homogeneous Zone of Pinerolo (HZP) (Figure 1), which is one of the 11 so-called homogeneous areas in which the Metropolitan City of Turin is articulated.
The HZP can be considered an interesting case for several reasons. First, despite the adjective "homogenous", the HZP is quite heterogeneous both in terms of socioeconomic factors and geographical structure. It includes 45 municipalities: a medium-size city, Pinerolo, which has over 35,000 inhabitants; 4 municipalities which have between 5,000 and 10,000 inhabitants; 25 municipalities between 1,000 and 5,000 inhabitants, and 15 small villages that have less than 1,000 inhabitants.
From a geomorphological point of view, the HZP can be divided into three parts: (i) an agricultural plain (12 municipalities), (ii) a hilly area around Pinerolo (10 municipalities) and (iii) a mountainous area bordering France and comprising three valleys stretching from one end to the other (Val Pellice, Val Germanasca and Val Chisone) (23 municipalities).
Tourism is a key sector for the HZP. While the highest mountain areas of the HZP are mainly a winter tourist destination, the hilly belt and the lower mountain areas are especially attractive for summer tourists (thanks to the proximity to the City of Turin).
In 2018, the HZP recorded over 460,000 overnight stays (60% more than ten years earlier); 45% of these stays were concentrated in the summer season (June-September), and 33% in the winter season (December-March). Mountain municipalities accounted for about three quarters of the stays. Finally, the HZP matches one

of the 33 Integrated Territorial Areas (AIT), that Piedmont Region in its regional Strategy for adaptation to climate change has identified as the more suitable administrative dimension to elaborate ad hoc adaptation measures.

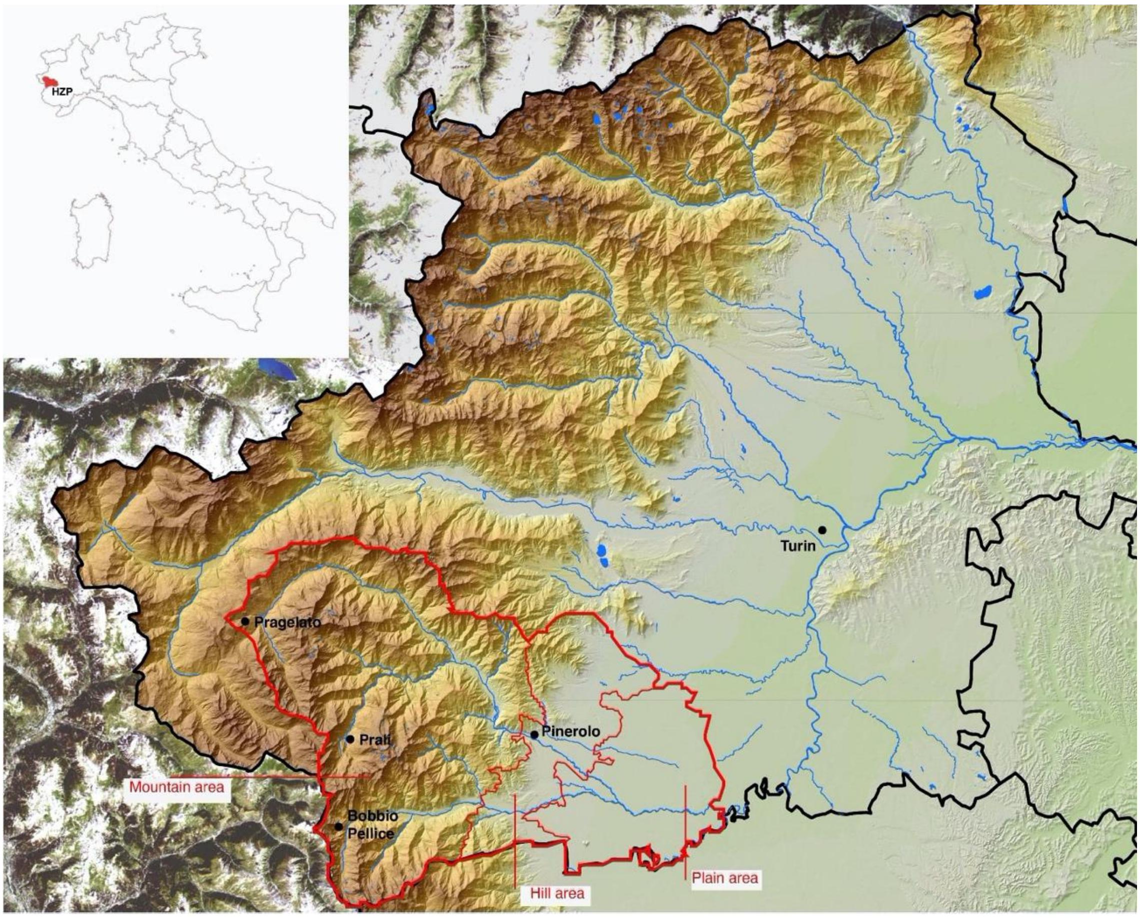

Fig.1 The Homogeneous Zone of Pinerolo

3.3 Climate, climate change and extreme events in the HZP

To analyse the climate changes, assessments and studies of its impacts are required for a length of at least 30 years (Bocchiola & Diolaiuti, 2010).

In the HZP, temperature and precipitation data have been regularly recorded from a local network of 13 meteorological stations, active since 1988.

The observed seasonal cycles of minimum and maximum temperatures from these records show that temperatures reach lower values in December and January, with a variable minimum temperature (Tmin) ranging between -5° and 0°C and a maximum temperature (Tmax) between 0 and 8°C. The maximum values are recorded between July and August, with the Tmax around 30°C and a Tmin of 18°C for the plain. Spring and autumn show intermediate and comparable values. Furthermore, the annual time series of maximum and minimum temperatures show an increasing trend with annual peaks of 1,5/2°C above the average level for the Tmax in some areas.

On the other hand, precipitation levels turn out to be very consistent in spring and autumn (with an average value over the area of about 300 mm), while winter is characterized by low rainfall of about 130 mm. Thus, while average values seem to follow the seasonal climatic trends, extreme values highlight critical issues in terms of magnitude and impacts on the territory.

For such reason, it is interesting to highlight some recent catastrophic events that affected the HZP. Since the 20th century, the area has been affected by seven major floods, listed in Table 2. These phenomena fell mainly in autumn and spring and have often resulted in landslides.

Date	Event
Oct - Nov 1945	Flood events combined with slope activities in the hilly area of the HZP. Impacts have affected the settlements, the infrastructures, the adjustments of defence to watercourses and roads, and have caused 2 deaths.
May 1949	A flood event due to an exceptional rainfall amount (it rained for over 5 days, with daily amounts up to 500 mm and a tip of 842 mm) mainly in the lower part of the HZP. The terminal sections of the Pellice and Chisone streams suffered the worst damage, in terms of arrangement and defence of waterways, agricultural land and roads.
May 1977	A violent flood event affected all the valleys of the HZP, destroying many city canal crossings and flooding many areas in the valleys. Several municipalities in the mountain zone recorded several damages on settlements, buildings, arrangements and defences of waterways, roads, and crossing-works. The event made 7 deaths, several injured and dozens of displaced persons.
Nov 1994	A flood event and the related slope activity affected all areas bathed by streams of the HZP, both in the plain and in the highest part of the territory. Damages on infrastructures, accommodations and water-defences, agricultural fields, roads, and public works were recorded.
Jun 1998	Several floods and landslides impacted on the hilly area of the HZP, with severe damages on the settlements, public spaces and infrastructures. The event made 9 deaths and several injured people.
Oct 2000	The flood event affected most of the HZP, with disastrous impacts on the infrastructures, accommodations, watercourse defences, agricultural fields, roads and yards.
May 2008	A stream flood with landslides provoked by intense rainfall hit part of the hilly and mountain areas of the HZP, with remarkable impacts on buildings, roads, infrastructures, sewer networks and sport facilities. The phenomenon made 12 deaths, 3 injured and more than 12 displaced persons.
Nov 2016	Flash flood events in the valley and part of hilly areas of the HZP affected the infrastructures, the watercourse-defences, agricultural land, roads and buildings, causing 1 death.

Tab.2 Main flood events in the last decades in the HZP, with associated local impacts

Regarding landslide and debris flow phenomena, some several active mass movements have been recorded in the HZP. These debris flows mainly affect mountain municipalities, but also the lower part of the valleys is threatened by conspicuous debris-masses. Moreover, the mountain portion of the HZP presents several areas at risk of avalanches. The database of Piedmont Region shows that the most numerous avalanche phenomena were recorded in 1969 (88 events), 1972 (73), 2008 (126) and 2009 (133), with an increasing trend in recent decades. Lastly, in relation to forest fires, the database of the Piedmont Region (which collects data from 1997 to 2016) recorded 211 events in this timespan, with an average annual value of 12.3 fires in the HZP, especially in the hilly zones. Despite a decreasing trend of events between 2007 and 2016, data highlight that January, February and November are the months with the highest average amount of burnt area due to fire events. This pattern is probably related to particularly dry autumns and winters.

4. Methodology

4.1 The risk assessment methodology

Based on the most reliable guidelines of institutions and organizations such as IPCC, United Nations, Covenant of Mayors for Climate & Energy EUROPE and the Alpine Convention (Bertoldi et al., 2018; Oppenheimer et al., 2014; Schindelegger & Kanonier, 2019; Zollner, 2018), the methodology here proposed identifies risks related to climate change as a function of hazard (H), exposure (E) and vulnerability (V) factors. The latter one is in turn divided into sensitivity (S) and adaptive capacity (AC). Each factor is here operationalised through specific indicators referred to tourism (Ellena et al., 2020; GIZ, 2017; Oppenheimer et al., 2014). In the case of winter tourism, the variation of the hazard related to climate change (H) is due to the increase in average temperatures as well as the decrease in snow precipitations (Croce et al., 2018). On the other hand, for the summer tourism exposed sample, the focus is on the increase of heatwaves, which will (indirectly) lead to longer stays in higher altitudes. The exposure samples (E) include indicators that consider the tourist offer as well as the main attraction capacities in relation to the analysed seasonal tourism. This to consider the link between tourism and economic flows together with the exploitation of existing natural resources in the area. Finally, Sensitivity (S) and adaptive capacity (CA), which refer to vulnerability (V), reflect respectively the

degree to which a system can be unfavourably (or beneficially) affected by climate change and the ability of this system to adapt or to cope with its consequences (Oppenheimer et al., 2014).
The following sections show in detail the indicators that have been measured at the municipal level for operationalizing each risk factor (Figures 2 and 3).

Fig.2 Hazard, Exposure and Vulnerability indicators for WINTER TOURISM

Fig.3 Hazard, Exposure and Vulnerability Indicators for SUMMER TOURISM

4.2 Hazard indicators

For climate hazards, reference climate periods and climate projections have been analysed using very high-resolution climate models. The evaluation of the historical period was carried out by using a subset of climate indicators based on temperature and precipitation, defined by the Expert Team on Climate Change Detection and Indices (ETCCDI) (Karl et al.,1999; Peterson et al., 2001).

Additionally, for the climate analyses, the observed daily gridded dataset NWIOI (resolution of 14 km) (Ronchi et al., 2008) over the 1981-2010 reference period was also considered to assess the observed values of these indicators. Climate variations were evaluated comparing the values of the 2021-2050 period, with respect to the baseline period (1981-2010).

The analyses have been carried out using an ensemble of high resolution simulations (about 12 km) from climatic models available in the framework of the program EURO-CORDEX(Ellena et al., 2020; Jacob et al., 2014, Jacob et al., 2020 ; Kotlarski et al., 2014). The representative concentration pathway (RCP) scenarios considered here were the IPCC RCP4.5 and RCP8.5 scenarios (IPCC 2014a). Table 2 shows the indicators identified as a proxy to evaluate the climate hazards. For winter tourism, changes in average temperature (TG) and decrease in snow precipitation (PRCPTOT) have been considered.

Additionally, the snow cover duration (SCD) was included in the analyses to evaluates the total number of days with snow depth higher than 30 cm between November and March (Durand et al., 2009; Marcolini et al., 2017; Valt & Cianfarra, 2010).

As explained in section 2.2, this indicator has been largely used in literature to evaluate the impact of climate change on the winter tourism (Scott et al., 2006). SCD is a key factor to characterize the decrease of snow cover for cross-country skiing (Marty, 2008) and it is an interesting indicator (mainly) for the municipalities of Prali and Pragelato, where there are downhill and cross-country ski slopes. Nevertheless, due to the very high correlation reported between the SCD and the previous indicators for winter tourism (TG and PRCPTOT) (i.e., 0.88, figure 4), it was decided to use only SCD to characterize the hazard for the winter tourism.

For summer tourism, the indicators that have been considered corresponded to those related to heat waves events such as HUMIDEX, HW, and TR (see descriptions in Table 3 for further details).

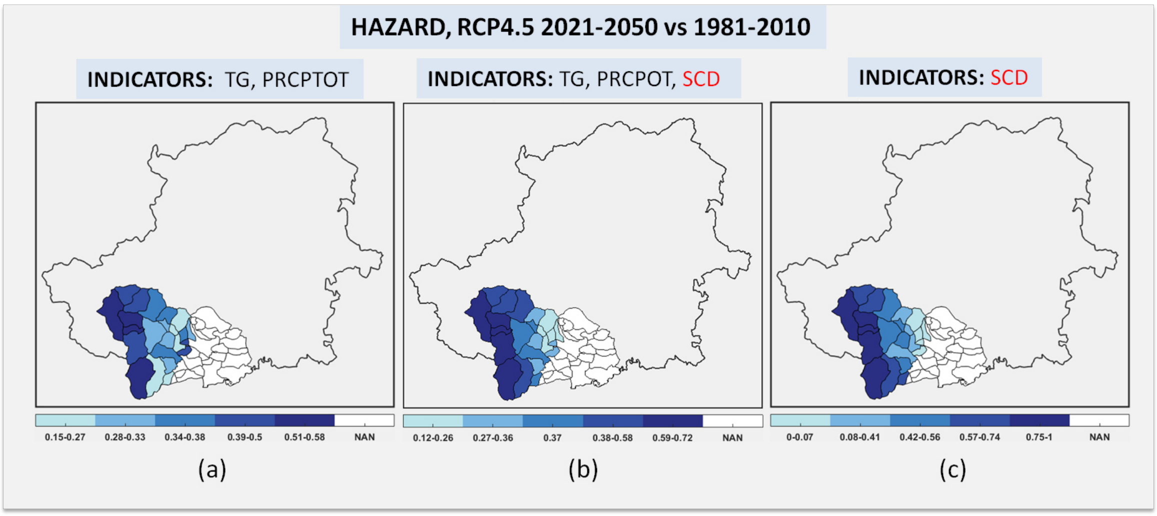

Fig.4 Hazard maps resulting from different sets of indicators: a) TG, PRCPTOT; b) TG, PRCPTOT, SCD; c) SCD

Season	Indicator	Description
Winter	Snow cover duration (SCD)	N° of days in a given snow season (from 1st Nov of a given year to the 31th Mar of the following year) with snow depth higher than 30 cm.
	[Annual total precipitation in wet days (PRCPTOT)]	Annual precipitation sum in wet days (days with precipitation greater than or equal to 1 mm).
	[Daily average temperature (TG)]	Average daily temperature per year (in °C).
Summer	Heat Waves (HW)	N° of days per year in which the daily maximum temperature is higher than 35 °C.
	Tropical nights (TR)	N° of days per year in which the daily minimum temperature is higher than 20 °C.
	HUMIDEX	N° of days per year in which the perceived temperature is greater than 45 °C.

Tab.3 - Hazards indicators for winter and summer tourism

4.3 Exposure indicators

For the exposure index, several tourist assets under climatic threats have been analysed (Emanuelsson et al., 2014; Oppenheimer et al., 2014). More specifically, the analysis considered the elements and the activities which could be directly or indirectly damaged by future hazard variations (Emanuelsson et al., 2014; Marzocchi et al., 2012). In the case of direct impacts for tourism, damages may affect tourism accommodations, winter-sports facilities, tourism activities and infrastructures. On the other hand, indirect impacts may refer also to interdependencies between assets (Ashley et al., 2005).

Table 4 shows the exposure indicators used as a proxy to evaluate the presence of touristic accommodation sites, services and sport structures and infrastructures.

Season	Indicator	Description
Winter and summer*	Accommodations	N° of accommodation sites for tourists
	Facilities	N° of infrastructures and facilities with a high landscape value
	Information	N° of information and reception offices for tourists
Winter	Sport activities	N° of winter sport centres
Summer	Hiking paths	Km of main and secondary routes, classified as cycling or hiking paths
	Cycling paths	Km of existing cycling infrastructures (paths and trails in green areas)

Tab. 4 Exposure indicators for winter and summer tourism

(*) This category belongs to indicators related to both winter and summer tourism

4.4 Vulnerability indicators

According to the IPCC (2014a, 2014b), in a risk-based conceptual framework, vulnerability can be assumed as a combination of sensitivity (S) and adapting capacity (AC). Consistently, within the current research context, both physical and non-material indicators (i.e., institutional adaptive capacity) have been considered, in coherence with local data availability (GIZ, 2017).

In the study, sensitivity indicators refer to the quantifiable physical touristic attributes of the selected area and correspond for the two seasonal scenarios (see Table 5).

Due to progressive data update, the latter refer to changes in tourist numbers from 2016 to 2017, since at the time of data processing the 2017 was the most updated year containing all data series for each HZP municipality. With regards to adaptative capacity, the indicators cover several aspects (Boyd & Juhola, 2015; GIZ, 2017; Master Adapt, 2018; Parry et al., 2007) such as: (i) knowledge, intended as general levels of education and awareness about climate issues; (ii) technology and engineering, meaning options that could ameliorate the adaptation process of a system; (iii) institutions, by looking at their role and capacity in guaranteeing sustainable resources-management and public participation; and, finally, (iv) socio-economic issues (e.e., GDP distribution, employment/unemployment rate, etc).

Accordingly, adaptive capacity indicators refer to these different aspects and are visible in Table 6.

Season	Indicator	Description
Winter and summer*	Arrivals	N° of clients hosted in the accommodation sites
	Presences	N° of nights spent by clients in the accommodation sites
	Duration of stay	Ratio between night stays and arrivals
	Tourist intensity	Ratio between number of arrivals and residents
	Receptive capacity	Maximum number of people that the accommodation sites can accommodate in one day or in the whole opening period
	Tourist flow variations	Changes in tourist visitors from 2016 to 2017

Tab. 5 Sensitivity indicators for winter and summer tourism

* This category belongs to indicators related to both winter and summer tourism

Season	Indicator	Description
Winter and summer*	Climate change initiatives	N° of local governments adherent to sustainability protocols
	Agriculture networks	N° of local agricultural networks where farmhouses, restaurants, bio-markets and urban gardens propose biological, traditional, good and equal products, food and social activities
	Eco museums	N° of eco museums with touristic proposals and guided tours
	Voluntarism	N° of institutions with volunteers
	Openness to sustainability	Sum of activities, bodies and initiatives related to sustainability. In particular, this indicator may include: institutions; municipal administrations; mountain communities or union of municipalities; national health service companies or bodies; public universities; non-economic public bodies; other legal forms.
Winter	Non-skiing activities	N° of tourist activities in the ZOP not related to skiing activities
	Artistic, social and cultural activities	N° of activities designed to satisfy various cultural and entertainment interests for the public, including live shows, museum management, games and betting, sports and leisure activities
Summer	Water scarcity measures	N° of provincial plans or strategies to tackle water scarcity in this season
	Fortification systems	N° of original fortification systems with touristic proposals and guided tours

Tab. 6 Adaptive capacity indicators for winter and summer tourism

* This category belongs to indicators related to both winter and summer tourism

4.5 Calculation of risk values

All the indicators described in previous sections were calculated for each of the 46 municipalities within the HZP. To be aggregated in Hazard, Exposure and Vulnerability indexes, all indicators were firstly normalised. Following the GIZ (2017) approach, there are three categories of scales that can be used to assess risk and vulnerability: metric, ordinal and nominal scale. Within this study, the metric scale was adopted.

The indicators were normalized by applying the Min-Max method (Ellena et al., 2020; GIZ, 2017; Master Adapt, 2018; OECD, 2007), so as to translate all values into a score between 0 and 1.

For some indicators, lower values reflect positive conditions (i.e., sensitivity), while in other cases lower values reflect negative conditions (i.e. adaptation).

In the latter case, an operation of "conversion" was made by reversing the direction of the value range in order to have all indicators in the same normalization ranking. Hazard, Exposure, Sensitivity and Adaptation Capacity indexes were calculated as a weighted average of their normalized indicators, while Vulnerability was calculated as the average of Sensitivity and Adaptation Capacity.

At the end, the final risk value for each municipality corresponded to the product of the values of Hazard, Exposure and Vulnerability.

5. Results

5.1 The 2050 scenarios

As mentioned in section 4.2, risk simulations were obtained according to the IPCC RCP4.5 and RCP8.5 scenarios, both for winter and summer tourism (IPCC, 2014a). The climate variations were assessed over the 2021-2050 period, compared to the 1981-2010 period.

For the winter tourism (Fig.5), the application of the methodology described in section 4 (limited to mountain and hilly municipalities, in which most touristic activities in winter are concentrated) highlighted two trends in the HZP.

In the 1981-2010 time-slot, the evolution of precipitation regimes and thermal increase (described in section 3.3) affected with more emphasis the municipalities in the lower valleys, which had to deeply reduce their ski touristic offer.

In addition, to provide more information on the current climate conditions, the calculation of the *snow cover duration* index (described in section 4.2) has been performed over the 1988-2018 period, based on observational data made available from ARPA Piemonte (2019) by in situ stations concerning daily snow depth. Only stations with information covering at least 75% of the reference period were retained, i.e., Pragelato-Traverses and Colle Barant.

The total number of days with snow depth higher than 30 cm between November and March is about 74 days for Pragelato – Traverses station, while the mean value is 38 days for Colle Barant station.

The future climate change in the 2021-2050 RCP4.5 scenario, conversely, will determine the major risks for the municipalities on the higher part of the valleys, with a further reduction in precipitations and an increase in temperatures.

These results are confirmed by the reduction of the snow cover duration index. In particular, the municipalities of Pragelato, Prali and Bobbio Pellice – which host the main ski activities of the HZP – will face the higher level of risks, due to both significant hazard and exposure.

It is interesting how, in the case of Prali and Bobbio Pellice, the risk is projected to be high despite a medium-low level of vulnerability (which is instead high in Pragelato). Moving down from these municipalities to the medium and lower portion of the valleys, the risk levels progressively decrease. However, in absolute terms, middle valley municipalities will be affected by growing climate hazards.

Results do not significantly change for the RCP8.5 scenario. These data therefore confirm a situation of increasing climatic risks for the upper valleys, mainly related to a decrease in snow cover duration (which in turn is due to an increase of average temperatures and reduction in precipitations). These trends pose the need for identifying diversified forms of alternative and sustainable tourism in winter, since to date the main activities focused on skiing.

With regard to summer tourism (see Fig.6), most of the relevant hazards related to temperature increases and heat-waves occurred in the hilly and flat part of the HZP during the 1981-2010 period. At the same time, mountain locations were significantly less affected.

Moving to the 2021-2050 period under the RCP4.5 scenario, climate projections show a progressive extension of the climatic risks to municipalities within the flat area, due to the temperature increase. On the contrary, for the mountainous zones, the levels of risk remain very low, despite the higher scores of exposure and vulnerability. This result is because hazard indicators are projected to stay unchanged for the mountain municipalities, while they will worsen substantially in the plain.

For example, the former will not record any increase in the number of days having a daily maximum temperature higher than 35°C, while this number will increase by 4-5 days in the latter. Even more evident is the trend related to tropical nights: their number will nearly remain unchanged in the mountain municipalities but will increase by 9-11 units in the municipalities within the plain.

In contrast, for mountain municipalities, the number of days having a daily maximum temperature higher than 35 °C is about 1 day/year, while the tropical nights are at most 2 days/year. Results for the scenario RCP8.5 do not significantly change by the previous estimates.

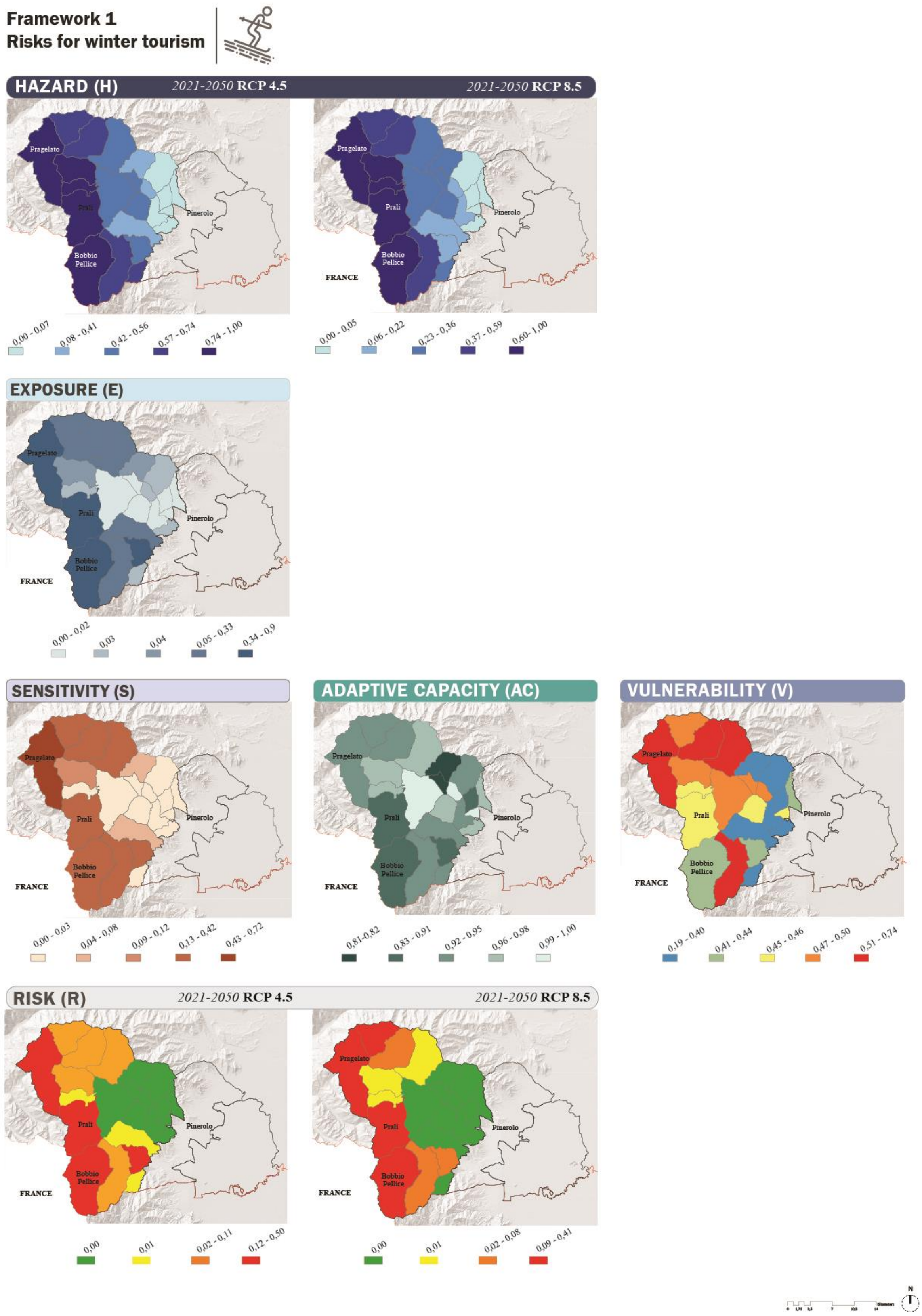

Fig. 5 Results for winter tourism

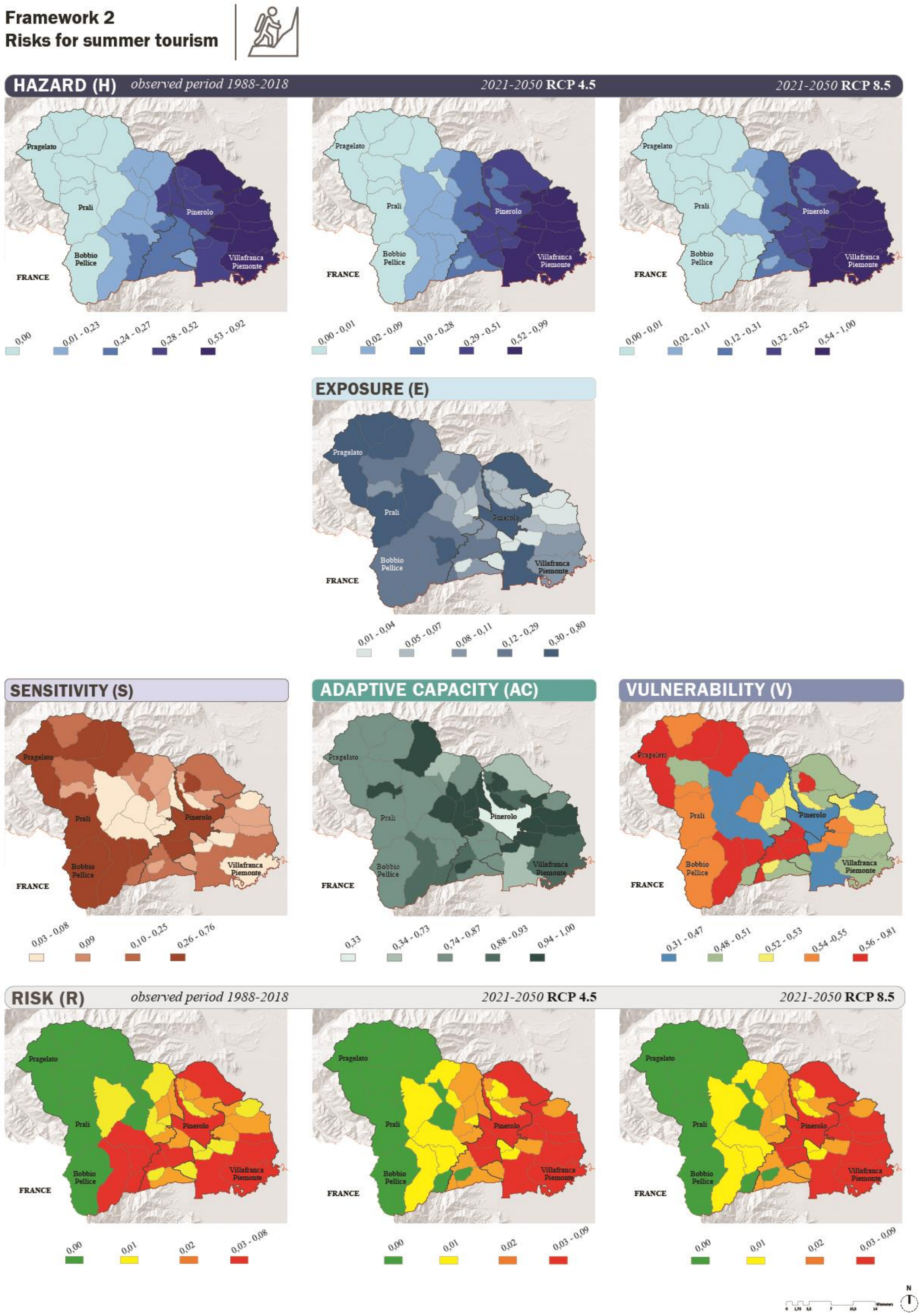

Fig.6 Results for summer tourism

These results indicate that an understandable increase in the duration of the stays in high altitude areas (less affected by heat waves) is expected for the summer season, at least partially compensating for the winter reduction. Therefore, these changes will increase the pressure on the to-date available resources (especially water and electricity).

5.2 Overlapping with extreme events related to climate change

A previous paper by Ellena et al. (2020) already analysed how hydrogeological hazards – such as flood, avalanches and landslides – are likely to change in the next decades in the HZP, leading to increased risks in the area for built settlements and infrastructural systems. In this section, implications of those risks for the tourism sector are examined. In general terms, hydrogeological instability will worsen due to two main trends: on the one hand, a general increase in maximum daily precipitation and maximum precipitation for 5 consecutive days, especially under RCP8.5 scenario; on the other hand, an increase in the number of days per year with a minimum temperature above 20°C, 25°C and 35°C. For what it may concern the risks for the built settlements due to flood, the higher risks are observed in the flat and hilly part of the HZP, while in the 2050 scenario the risk will change in particular in the mountain areas, following opposite trajectories. In fact, the risk will increase in Chisone valley (in particular in Pragelato), while it will decrease in Germanasca and Pellice valleys. These differences are mainly related to the exposure, which in these cases is very high in Chisone valley and much lower in the other two valleys. On the contrary, the risks related to flood for the infrastructural systems will increase mainly in the plain and on the hills of the HZP, which turned out to be more vulnerable to these hazards. In this case, the more touristic municipalities in the mountain part of the HZP are not significantly affected by risks. However, they could be indirectly affected, as their accessibility depends on the availability of transport infrastructures in the plain. Namely, if a flood makes these infrastructures unusable, tourists cannot reach the HZP valleys.

As pointed out in *section 3.3*, flood events tend to concentrate in spring and autumn, i.e. the seasons in which the presence of tourists in the area is lower. However, the damages that these events can cause are often relevant and cannot be repaired in a short amount of time. Therefore, floods can have significantly negative impacts on both winter and summer tourism.

Looking at landslides and avalanches, to date the maximum level of risk both for built settlements and infrastructures is concentrated in the medium part of the mountain valley, while in the 2021-2050 scenario this risk will move to the higher part of these valleys, where most touristic activities take place. Avalanches pose a serious danger for ski mountaineering and other outdoor sports in the winter, while an increased frequency of landslides could discourage activities in the summer, as well as interrupt roads and transport services that ensure accessibility in the HZP. Finally, also the hazard related to forest fires – until now stronger on the hilly part of the HZP – will progressively move in the next decades toward the mountain municipalities. In this case, however, risks for the built settlement will become very high in Pellice valleys, while they will remain low in Chisone and Germanasca valleys thanks to the reduced levels of exposure.

6. Discussion and conclusion

This paper develops and tests a risk assessment methodology to analyse how potential positive and negative impacts of climate change on winter and summer tourism will spatially distribute on a 2021-2050 scenario within the HZP. Since a singular case study was considered, any claim of exhaustiveness and systematicity must be excluded; however, some interesting issues emerged from the results of the application, both in substantial terms and regarding methodological aspects. Overall, the elaborated risk maps are consistent with the review of the literature carried out in section 2. The high-altitude municipalities are going to face the greatest impacts due to climate change, although in opposite directions when considering seasonality. This scenario has direct consequences for the mountain landscape, environment, and tourism. In winter, reduced snow cover duration will threaten ski activities, which are the main attraction for tourists in this season. After the '80, this reduction already involved the dismantling of ski facilities in the medium part of the HZP valleys. In the next decades, also Pragelato and Prali will need to concentrate skiing activities at altitude over 1,500 meters. Moreover, the inter-annual and intra-annual variability of snow fall and cover will increase, intensifying the complexity in managing ski activities. Nowadays, snowmaking and its related investments are the most widely implemented adaptation measures to face climate change for winter tourism sector. However, its environmental and economic sustainability is limited. Even if many snowmaking facilities are improving their resource consumption (in water and energy), the deterioration of landscapes and changes in natural ecosystems are inevitable side effects of this activity. Damages are caused by the creation of additional pressure on water reservoirs, water plumping, slope expansion, soil erosion and other issues. The climate projections and their direct and indirect impacts on risk assessment could help authorities and stakeholders to build new long-period visions of winter tourism for these territories. In this sense, it will be crucial to promote diversified winter attractions for tourists less focused on snow.

The negative risks for the winter season could be partially balanced for the high-elevation municipalities by increased opportunities related to the summer tourism. In fact, in the summer months the tourism is projected to become more appealing in the higher valleys due to the milder temperature. Moreover, these areas will be less hit by heat waves than the hills and the plain.

As a consequence, HZP mountains could become the destination of tourists from the near metropolitan area of Turin during weekends, especially during the hottest months (i.e. July and August). This sort of "renaissance" of the Alpine summer tourism (Abegg, 2011), which might be pushed further by the current COVD-19 pandemic (De Luca et al., 2020), could however also lead to an increased pressure on local water resources.

Therefore, there could not be sufficient water to fulfil the demand along the tourism seasonal peaks, although melting glaciers may compensate for short-term hydrological scarcity (Hohenwallner et al., 2011). These direct primary effects could be exacerbated by secondary effects of climate change, which will likely increase frequency and magnitude of extreme natural events just in those high-elevation parts of the HZP. A foreseen intensification of flood events in spring and autumn could cause damages to the built settlement of these areas, as well as to the infrastructures that ensure accessibility for tourist flows. These results should support local authorities in strengthening the traditional policies applied in terms of urban planning, building materials, architecture, distribution of green spaces, public services, etc. Avalanches and landslides will determine major risks not only for settlement and infrastructure systems, but also for winter and summer tourism activities like skiing, free-ride, hiking, climbing, mountain biking, and so on. Also, wildfires seem likely to be intensified due to extreme temperature and precipitation conditions. If it is true that these results are broadly in line with the main literature findings, it emerged from this study how they cannot be easily generalised, even within an area with limited extension, such as the HZP.

The same climatic hazard levels can lead to very different levels of risk even in neighbouring municipalities, if they show different conditions of exposure, sensitivity and adaptive capacity. This was found in many simulation results, particularly when comparing risks between the upper and middle parts of mountain valleys, but also among the upper municipalities themselves in relation to flooding and forest fires. In this sense, the proposed methodology can be a useful decision support system for identifying priorities in adaptation strategies and plans, especially in cases such as the HZP, which is in charge of the elaboration and implementation of these plans within its boundaries (Francini et al., 2021). A consideration of expected trends in climate hazards, combined with analyses of local exposure and vulnerability levels, can help to recognise how risks and opportunities are spatially distributed within a given Alpine area. A multi-level approach can indeed help to answer the following questions: i) which municipalities require urgent interventions? (ii) which ones, on the contrary, present low levels of risk, so that their tourist offer can be immediately promoted and valorised to support the overall attractiveness of the area? Alongside to these points, some limits of the proposed methodology have to be acknowledged. In the analysis, the collection of exposure indicators was affected by the lack of complete and reliable data-series on local tourism.

This deficiency somehow limited a broader collection of touristic elements/activities[1] which could be directly or indirectly affected by climate change hazards.

First, the inclusion of some indicators in the calculation of exposure, sensitivity and adaptation capacity indexes was not possible because of the lack of data availability. To exploit all its potential benefits, the proposed methodology requires rich bases of municipal or even sub-municipal data, which are often poorly available, especially for rural and mountain areas outside urban agglomerations. Second, the selected indicators have been aggregated in hazard, exposure, and vulnerability indexes, without being weighted according to their relative importance. The inclusion of different weights (possibly defined through participatory approaches that involve local stakeholders) would improve the significance of the indexes used in the calculation of the risk levels. Finally, in a view of determine which area to prioritize, the risk values are not expressed in absolute values, but in relatives, therefore the maps show how much a certain municipality is more/less "at risk" than another one. This imply difficulties to compare how risks increase or decrease based on different future time periods and RCP scenarios. Therefore, further research is welcome to overcome these limits and improve a methodology that can help to identify trans-sectorial adaptation measures to face challenges and seize opportunities for the Alpine tourism, according to that "policy integration" called for by Becken et al. (2020) just in relation to tourism and climate change.

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[1] In case of a broader availability of data on local tourism, other exposure indicators may include: the tourism climatic index (TCI) proposed by Mieczkowski (1985), the tourism contribution to local economy (% of GDP), the workforce (% of total employees in local tourism activities), the percentage of employees in the sector with low education, the trade balance in travel (to the HZP) (% of GDP), etc.

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Image Sources

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