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Climate assessment report

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Abstract

The project aims to valorise, develop and manage periurban landscapes with their natural and cultural assets as part of the blue and green infrastructure network for a liveable and attractive Trento. Suburban public green and agricultural areas shall reconnect the city with the river Adige since the valley floor suffers from urban sprawl and infrastructures of the Brenner axis.
The city is currently questioning on how to understand, valorise, develop, and manage periurban landscapes with their natural and cultural assets as integral part of the larger blue and green infrastructure BGI network for a liveable and attractive Alpine Space. The alpine features and the natural and productive landscapes (agriculture, recreational, cultural sites) are the background of the project. It explores the multifold identities of infrastructures in the Alpine context, enhancing them into contemporary definitions of green and blue infrastructures.

Trento Urban Challenge

Marginal[mahr-juh-nl]
adjective
1. pertaining to a margin.
2. situated on the border or edge.
3. at the outer or lower limits; minimal for requirements; almost insufficient.

Trento's urban challenge for its future development consist on the activation and regeneration of **marginal areas as potential urban reserves for community, microclimate, productivity and excellence**. This challenge accomplishes the European goals (EU Urban Agenda) and the guidelines of the review of the urban plan, such as zero consumption soil, valorisation of agriculture, efficient governance of water usage, valorisation of landscape, preservation of environment and biodiversity, and the climate change (microclimate and urban heat island). The **marginality** is the expression of a spread condition of inactivity, obsolescence, decommissioned of numerous areas in the valley of public and private properties.

At the urban scale, generally, marginality has a negative connotation since it identifies an area on the margins of something, a place of low quality, a residual space that very often lies in a state of obsolescence. Several areas along the valley of Trento are dealing with this condition: they are **fragmented** and **marginal** area as well as **weak, inactive, unused or even almost unknown areas**.

These areas are contiguous to urban, industrial and/or productive districts as well as to infrastructures, river and agricultural fields that all have significantly impacted on the definition of their marginal condition.

In some cases these areas are in opposition to the historic city but in the majority of cases they penetrate into the urban and productive city by leaving empty spaces, characterized by abandonment, and environmental and social decay. In other cases, they used to have an agricultural function in the recent past but today they are wild and uncultivated, exposed to phenomena of productive marginalization forced by the pressure of the surrounded urbanization, mobility infrastructures or progressive abandonment of agricultural activity. Marginality is thus defined not as a general concept but it has to be declined in relation to the surrounding contexts: the urban centre, the productive agricultural areas of the valley floor, the riverfront system.

The project aims to offer a new point of view on the above-mentioned areas by highlighting their possible positive elements that they may have within the urban/territorial systems and by offering space for experimenting innovative devices and tactics to reach climate adaptation. The main objective is **to activate a process of valorisation, knowledge, awareness and implementation** of the urban fragments through their rediscovery and communication of their potentialities.

The project aims to enhance, develop and manage **marginal landscapes** with their natural and cultural assets as part of the **Blue and Green Infrastructure (BGI) network for a livable and attractive Trento.** BGI have a pro-active role to enhance actions for mitigation, adaptation, reduction of climate change risks, preservation of biodiversity.

The outcomes are oriented to the supply of **measurement, evaluation, monitoring and/or communication of values of Trento's marginal areas**. The proposed projects should increase environmental, urban and architectural quality as well as provide for **a fair distribution of services, territorial provision, infrastructures for a better management of mobility, community, as well as for the reduction of abandonment and decommissioned areas**. They also may involve measures prone to diversification of rural economy and maintenance or recovery of urban quality, especially regarding ecological regeneration of the urban settlements. For example, systems for emissions monitoring, technological disposals, data collections and integration or management resources could be developed.

The results show concrete responses by proposing **services to reactivate and recovery** these areas as new multifunctional spaces but also **to communicate and share values**. Projects can support the transformation of the physical space of the urban environment by applying to one or more of the following **quality objectives**:

a. recovery and regeneration of marginal areas characterized by underuse or abandonment (e.g. landed areas or areas awaiting to be reclaimed) and subjected to deterioration phenomena (e.g. marginality, sprawl, structural or infrastructural deficiency, unsuitability of services);

b. interventions able to enhance and promote cultural and natural heritage, for example through projects of street furniture, improvement of accessibility and usability of spaces, improvement of pedestrian mobility and re-evaluation of existent accommodation and catering facilities.

c. evaluation and monitoring of climatic and environmental quality (systems of air, water and soil) through innovative technological systems which can integrate the database availability of the environmental institutions of the territory (Province, Municipality, Research centres, Valley Communities, Associations, etc.).

Baseline

1.1 Introduction

The identification and development of urban measures capable of mitigating and adapting to climate changes are primarily represented by the Local Climatic Profile, which describes the existing conditions and the climatic variability of a territory.

In this chapter, a base of the principal climatic features of the Province of Trento will be traced with a particular interest in the urban area of Trento. The objective is to enable users to understand the main vulnerabilities and risks connected to a changing climate in the valley floor of the Province of Trento. The analysis of climate variability, both for mean and extreme values, has been done for a 30-year period.

IPCC reports are considered the primary reference and they give evidence of an unequivocal global warming, an increase of mean values of global surface and ocean's temperature, ice caps retreat, global sea level rise; they show that the majority of the temperature increase has occurred in the second part of the 20th century.[1]

The relationship between climate changes and extreme events is increasingly evident and there is a general consensus in the international scientific community in attributing the causes to the constantly increasing greenhouse gases due to human activities. Extreme events like droughts, heat waves and floods are ever more frequent and they are threatening our ecosystems as well as the stability of economic systems and wellbeing of future generations.[2]

For the reasons stated above, we can't think about climate changes as just one of the most relevant environmental problems, but also as one of the most serious economic threats we have to face actions in different fields (e.g. political, economic, regulatory) are essential as well as new strategies in planning cities, engaging the energetic sector, reducing emissions, introducing new systems of sustainable development and managing resources properly. In fact, investing to face and control impacts to climate change is more economically convenient than refurbishing urban environment after damages caused by extreme events.[3]

1.2 Regional climate change: an overview

The Province of Trento boasts a good climatic data set, which is the base to recognize and trace trends that will probably continue – or even gain strength – in the next decades. The most complete climate analysis of Trentino can be found in the "Climate Atlas", a web-based set of data and thematic reports on climate and its change[4].

A previous, commented, report on climate indices was issued in 2012[5] where 39 daily meteorological series of precipitation and temperature were used spanning over all the altitudinal range of the region, even if with different territorial coverage. The scientific baseline on the past climate changes, regarding temperature and rainfall, is shown below.

Temperature

Due to its Alpine territory, **in Trentino the temperature regimes are strictly connected to the terrain elevation**. As in any mountain territory, a vertical negative gradient of mean temperatures exists, all along the year, but more pronounced in the summer. [6]

[1] IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[2] EEA(2012).Urban adaptation to climate change in Europe Challenges and opportunities for cities together with supportive national and European policies, EEA technical report 2/2012

[3] Carraro C. e Mazzani A. (2015), Il clima che cambia, non solo un problema ambientale, Il Mulino: Bologna.

[4] Climatlas on the web: https://climatlas.fbk.eu/

[5] Di Piazza, A e Eccel, E. (2012), a cura di Osservatorio Trentino sul clima, Dipartimento Protezione Civile, incarico Dirigenziale per la Programmazione di protezione civile. Analisi di serie giornaliere di temperature e precipitazione in Trentino nel periodo 1958-2010, Litotipografia Alcione: Trento.

[6] Portoni M. (a cura di) (2008), Progetto clima 2008, Previsioni e conseguenze dei cambiamenti climatici in Trentino, Provincia Autonoma di Trento.

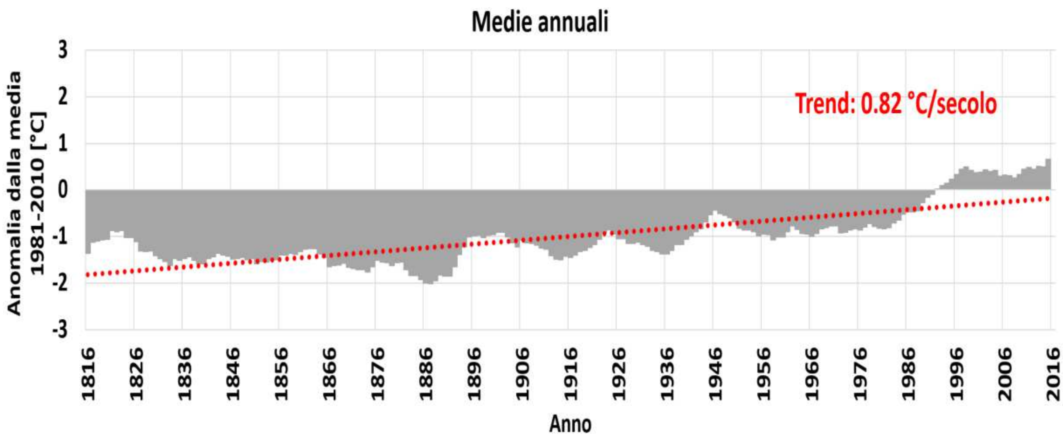


Figure 1. Anomaly of mean annual temperatures in Trentino in the period between 1981-2011.

There is a general consistency in the temperature series recorded in Trentino, even if singular features can be found at particular locations. In general, in the period considered the temperature trend has increased more and more during the past 150 or 200 years[7]; in the last 200 years it has been assessed as 0.8 °C/century (Figure 1), increasing to 1.34 °C/century considering the last 150 years, to 1.83°C/century considering the last 100 years and reaching 3.64 °C/century considering the last 50 years[8]. Such high rates are also a consequence of the influence of the urban heat island effect, which leads to an increase of temperature of about 0.1°C/century[9].

Precipitation

Any trend involving precipitation must consider the presence of oscillations in its regime. In general, only minor changes have been observed in Trentino. If the latest period (1991-2016) is compared to the long-term one, 1961-2016, it can be seen that only in autumn there is a clear increasing trend, and a small decrease has been recorded in spring, while in other seasons changes are minor, with some exceptions (e.g., in the stations reported in Table 1: Malé and Tione in spring).

PERIOD	Trento L.	Lavarone	Cavalese	Tione	Rovereto	Malè	Predazzo	MEAN
Year	4%	4%	1%	0%	1%	-1%	11%	3%
Winter	2%	1%	-3%	2%	-1%	-3%	6%	1%
Spring	-2%	-5%	-4%	-11%	-7%	-13%	3%	-6%
Summer	3%	3%	0%	-3%	-1%	-2%	10%	1%
Autumn	12%	14%	11%	10%	10%	10%	21%	13%

Table 1. Mean seasonal and annual changes in rainfall rates, 1991-2016 vs. 1961-2016. Source: Meteotrentino

Extreme events are, in some cases, increasing; at some stations, values in the top rank of distribution (like 95th or 99th percentile) have increased, but this is not a general rule for Trentino.[10]

[7] Zaniboni, L., Zardi, D., Giovannini L., Ricostruzione e analisi della serie storica delle misure di temperatura dell'aria rilevata nella città di Trento nel periodo 1816-2015, available at: http://www.climatrentino.it/binary/pat_climaticamente/osservatorio_trentino_clima/Serie_storica_temperature_Trento_parte_I.1496738821.pdf

9 Bellin, A. e Zardi, D. (a cura di), Analisi climatologica di serie storiche delle precipitazioni e temperature in Trentino, Quaderni di idronomia montana, n. 23 (2004), Provincia Autonoma di Trento
[10] Di Piazza, A e Eccel, E. (2012), a cura di Osservatorio Trentino sul clima, Dipartimento Protezione Civile, incarico Dirigenziale per la Programmazione di protezione civile. Analisi di serie giornaliere di temperature e precipitazione in Trentino nel periodo 1958-2010, Litotipografia Alcione: Trento.

Observing a drier climate

When aridity / humidity indices are calculated and compared for several decades, a general signal to a drier climate is evident, mostly driven by the **higher temperatures**. Eccel[11] considered four different humidity indices and calculated their values for the two 30-year periods 1961-1990 and 1981-2010 for 29 stations in Trentino. The result was that, under present conditions, in 3 cases the classification was of a more humid type in present times, while in 10 cases it was of a more arid one; the other cases showed no shift in aridity classes according to the different definitions.

1.3 Local climate change: Trento and its province

The complexity of the morphology of the Province of Trento leads to a variety of different climatic features: the valley floor, where the town of Trento lays, has a temperate climate. According to Köppen – Geiger, it can be classified as a type "Cfa" (moist temperate, with no dry season, with hot summer). Given its position in a rather narrow valley, **light breeze winds flow for most of the year, preventing the area from being both excessively hot in summer, and moist, even in the colder months**. For the same reason, fog is an extremely rare and transient phenomenon. The northern outskirts of the town, during the afternoon of spring and summer months, experience a particular wind, named "Ora del Garda", that flows from lake Garda through the Sarca Valley to the Adige Valley.[12] More information on wind regime can be sought at the "Trentino wind atlas"[13].

1.3.1 Trends of climate change

Temperature

Mean regime

Observing mean temperature values of the station of Trento (Figure 2), an **increasing trend of annual mean temperature** is clear and it has been particularly evident since the late 19th century, but strengthening in the most recent decades. Mean seasonal temperatures registered increases especially in the sunny seasons (Spring and Summer), but significant in all the periods of the year.

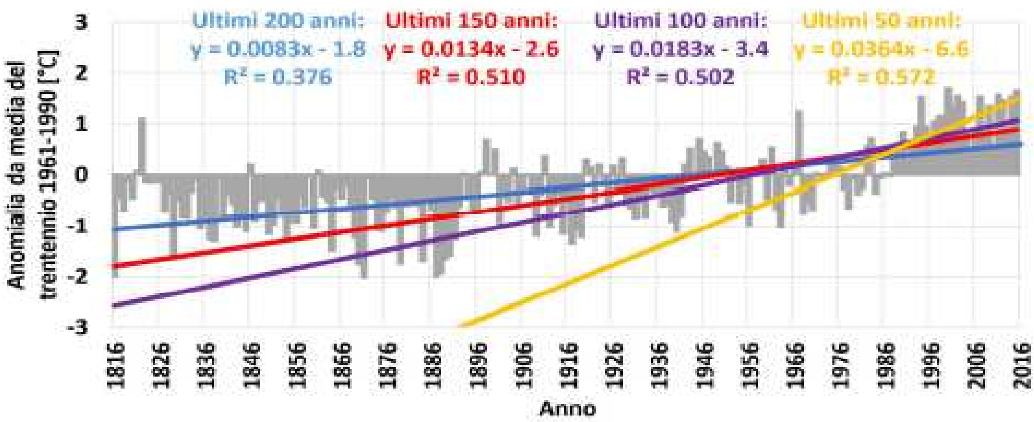


Figure 2. Station of Trento: 200-year annual temperature trends.

[11] Eccel E. (2015): Progetto Indiclima – Elaborazione di indici climatici per il Trentino. Relazione finale.
[12] Giovannini L. et al., Analysis of the Urban Thermal Fingerprint of the City of Trento in the Alps, American Meteorological Society vol.50(2011):1145-1162), DOI: 10.1175/2010JAMC2613.1
[13] https://climatlas.fbk.eu/atlanteeolico/

In many stations in Trentino, including Trento, maximum values have recorded a higher positive trend compared to minimum temperatures.[14]

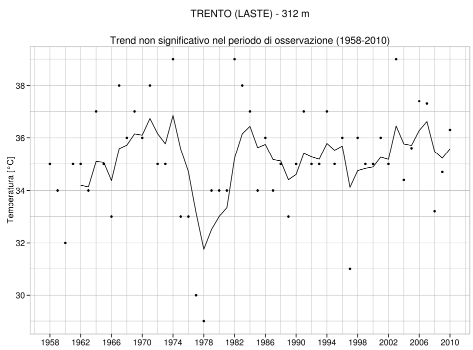
Nome Stazione	Periodo	Temperatura media dei trentenni di riferimento [°C]			Anomalie rispetto al periodo 61-90 [°C]		Trend temperatura media / Errore standard [°C/decennio]			
		61-90	71-00	81-10	71-00	81-10	61-90	71-00	81-10	58-10
TRENTO (LASTE)	anno	16,8	17,1	17,5	0,4	0,7	0,39 ± 0,16	0,36 ± 0,13	NS	0,35 ± 0,06
	inverno	5,4	6,2	6,4	0,9	1,0	1,01 ± 0,28	NS	NS	0,53 ± 0,12
	primavera	17,9	18,5	18,9	0,7	1,1	NS	0,90 ± 0,23	NS	0,45 ± 0,11
	estate	27,4	27,7	28,2	0,2	0,8	NS	NS	NS	0,33 ± 0,12
	autunno	16,2	15,8	16,3	-0,4	0,0	NS	NS	NS	NS

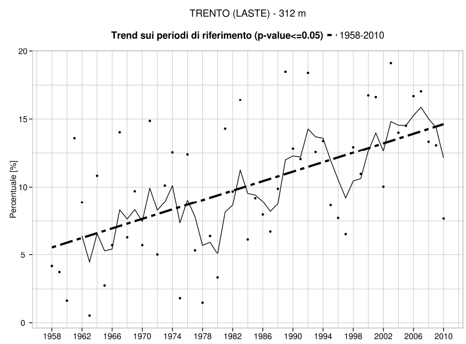
Nome Stazione	Periodo	Temperatura media dei trentenni di riferimento [°C]			Anomalie rispetto al periodo 61-90 [°C]		Trend temperatura media / Errore standard [°C/decennio]			
		61-90	71-00	81-10	71-00	81-10	61-90	71-00	81-10	58-10
TRENTO (LASTE)	anno	7,4	7,5	7,8	0,1	0,3	-0,32 ± 0,12	NS	0,59 ± 0,07	0,12 ± 0,05
	inverno	-1,6	-1,4	-1,4	0,2	0,2	NS	NS	0,82 ± 0,21	NS
	primavera	7,4	7,6	7,9	0,2	0,5	NS	NS	0,59 ± 0,20	NS
	estate	16,0	16,1	16,5	0,2	0,5	NS	NS	0,46 ± 0,14	0,21 ± 0,08
	autunno	7,8	7,4	7,8	-0,4	0,1	-0,60 ± 0,22	NS	0,54 ± 0,19	NS

Figure 3. Temperatures at Trento Laste station in the three reference periods 1961-'90, 1971-'00, 1981-'10, with trends for the periods; upper panel: maximum temperature; lower panel: minimum temperature (from Di Piazza and Eccel, 2012).

<u>Maximum values.</u>

Absolute maximum values in Trentino have recorded a mostly significant trend (less clear in the station of Trento Laste).[15] As well, a strong increase can be measured in the number of "hot summer days" and "hot summer nights".





[14] Di Piazza, A e Eccel, E. (2012), a cura di Osservatorio Trentino sul clima, Dipartimento Protezione Civile, incarico Dirigenziale per la Programmazione di protezione civile. Analisi di serie giornaliere di temperature e precipitazione in Trentino nel periodo 1958-2010, Litotipografia Alcione: Trento

[15] Di Piazza, A e Eccel, E. (2012), a cura di Osservatorio Trentino sul clima, Dipartimento Protezione Civile, incarico Dirigenziale per la Programmazione di protezione civile. Analisi di serie giornaliere di temperature e precipitazione in Trentino nel periodo 1958-2010, Litotipografia Alcione: Trento

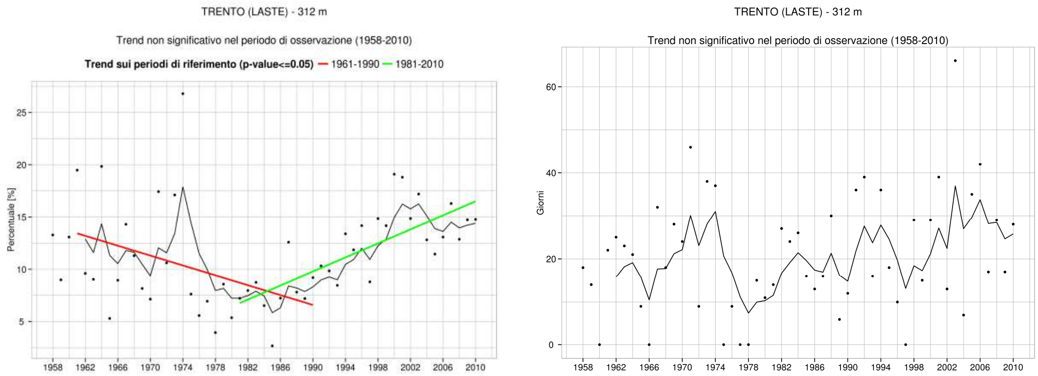


Figure 4. Hot temperature indices for the station of Trento Laste, 1958-2010. Left to right, top to bottom: number of days with maximum temperature above the 90th percentile of 1961-1990, number of days with minimum temperature above the 90th percentile of 1961-1990, heat waves index.

The "heat waves" index has not increased in the town, unlike at most other sites in Trentino. The figure below (Figure 4) represents the hot temperature indices for the station of Trento Laste registered between 1958-2010.

<u>Minimum values.</u>

Consistently with the trends described above, cold temperature indices (number of "winter days", number of frost days, and cold-spell index, which are reported in Figure 5) have decreased in Trento, especially in the latest decades, confirming the general trend at the other sites in the region.

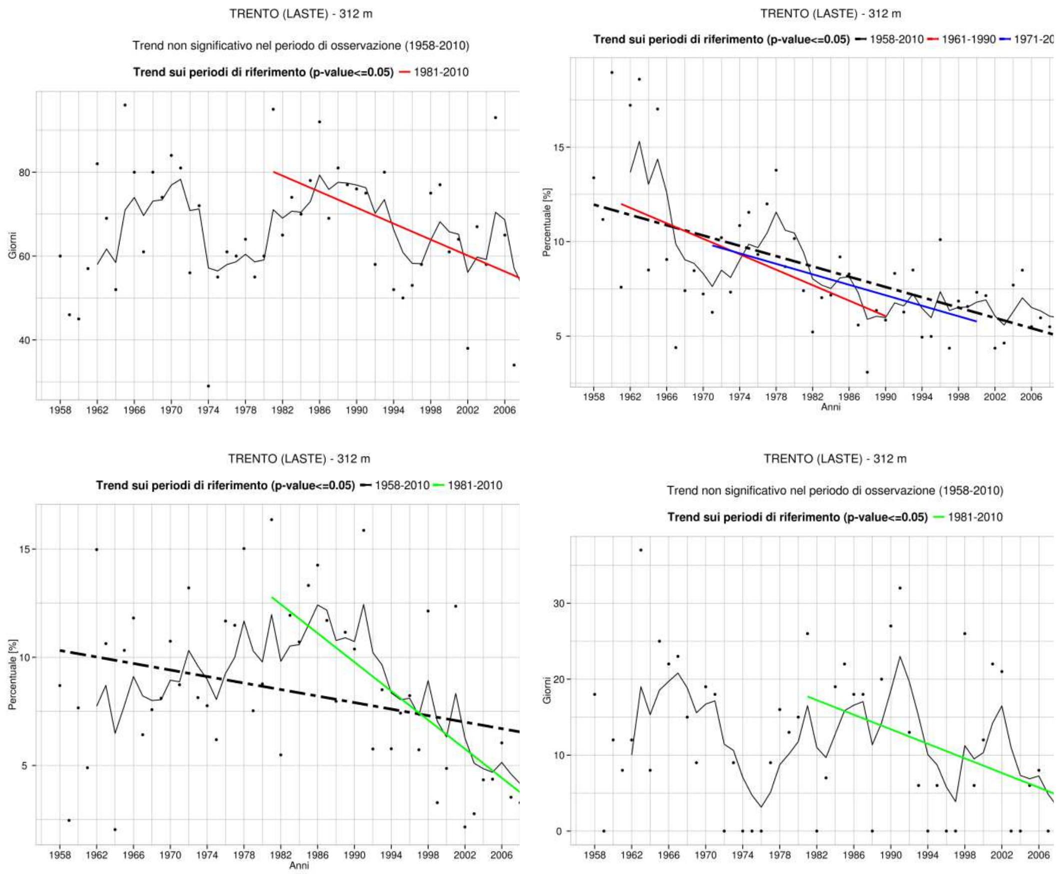


Figure 5. Cold temperature indices for the station of Trento Laste, 1958-2010. Left to right, top to bottom: frost days, number of days with maximum temperature below the 10th percentile of

1961-1990, number of days with minimum temperature below the 10th percentile of 1961-1990, cold waves index.

Rainfall

Mean regime.

Precipitation in the area of Trento has a mean annual depth of 936 mm. There is no dry season, although the winter is less rainy. **Mean monthly rainfall rate increases from March to May, remaining then in the highest range until November**. The month with deepest precipitation is on average October (above 100 mm). Full summer months are usually less rainy than the late Spring and Autumn, but they never fall below rates around 10 to 30 mm, which, on the contrary, may well occur in other periods; this may occur even in the autumn months, but especially in winter, when completely dry months are not rare.

Intense, short-duration precipitation.

Intense precipitation is able to cause breakdowns in the urban drainage systems. Typically, the critical duration of such intense events is less than 1 hour. A climatology of sub-daily precipitation was carried out by Eccel (2015). In this analysis, the shortest integration time was 1 h; shorter times would need long-enough series, which are seldom available.

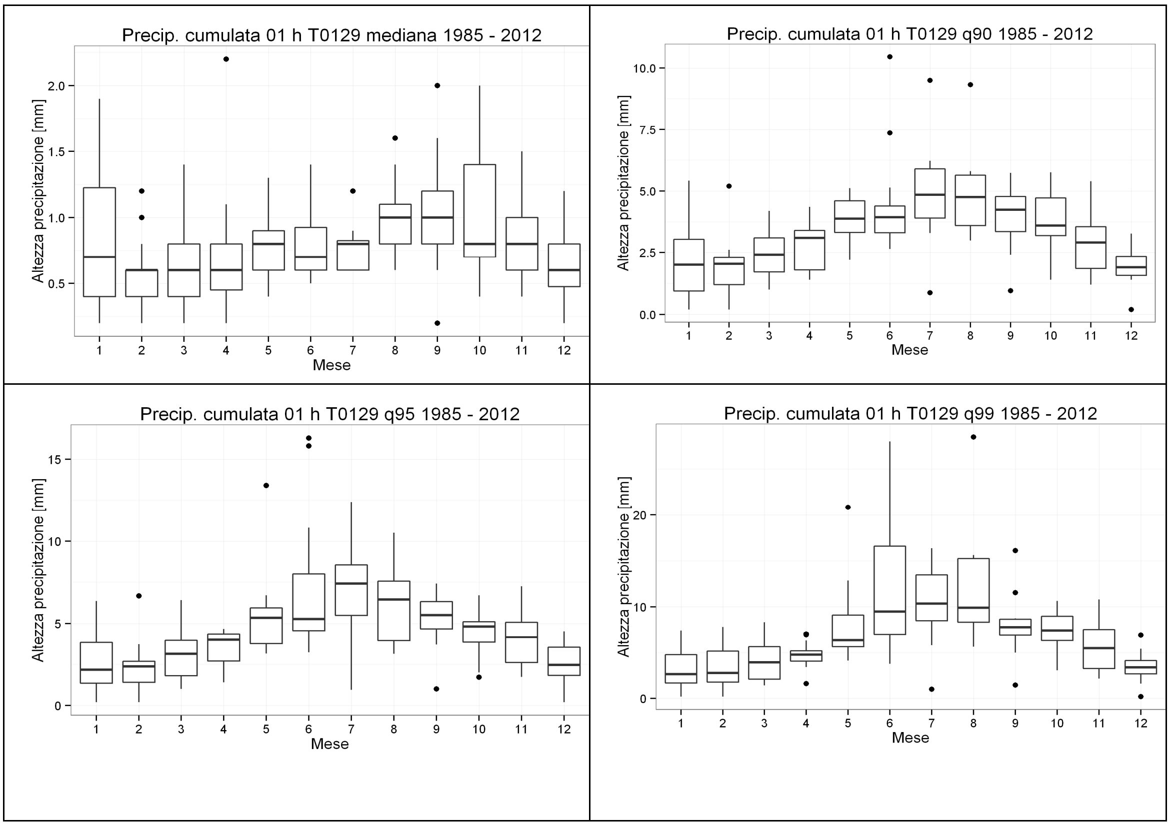


Figure 6. Climatology of 1 h precipitation events at Trento Laste station. Median (50th percentile) to 99th percentile. From Eccel, 2015.

If we consider 1 h precipitation rates (Figure 6), it is easy to understand that, the more we approach the highest positions in the percentile scale - that is, the closer the events are to the absolute maxima[16] - the higher is their probability to occur in the summer. This because the strongest atmospheric dynamics in

[16] Trento Laste has a mean annual number of rainy days of about 84, so the 99th percentile is very close (slightly higher) to the absolute maximum

summer can generate more intense events than in colder months, despite the highest number of disturbances occurring in autumn and in spring. Hence, the intense precipitation rate is potentially linked to the atmospheric instability conditions in summer; this is to be considered in changing climate conditions, even when the general rainfall rate is expected to decrease in summer.

1.3.2 Future scenarios of climate change in Trentino

The most recently published climate change simulations for Trentino are described in Eccel et al. (2016). They considered two IPCC scenarios (RCP 4.5 and RCP 8.5), for two future time windows (2021–2050 and 2041–2070).

The simulations predict a general decrease of total rainfall and number of rainy days, but an increase in both mean precipitation depth on wet days and precipitation maxima. Furthermore, the number of consecutive dry days is expected to increase, while the number of consecutive wet days is expected to decrease. The signal is generally more intense for the more pessimistic scenario RCP 8.5.

For temperature, a continuous and significant increase is predicted, more intense according to scenario RCP 8.5 and for the more distant future period (2041–2070). Accordingly, the numbers of frost and ice days (days with Tmin < 0 °C and Tmax < 0 °C, respectively) are expected to decrease and the number of summer days (days with Tmax > 25°C) to increase.

The climatic warming is able to determine in some cases a shift in the climate types. Table 2 reports the number of stations belonging to the climatic types and sub-types of Köppen – Geiger's classification of climates.

Particularly, a strong and continuous increase is predicted in the number of "Cfa" sites, representative of the "hot summer" valley-bottom conditions.

Period &	'76-'05	'21-'50		'41-'70	
RCP scenario		4.5	8.5	4.5	8.5
Cfa	6	11	11	15	17
Cfb	24	21	21	19	20
Cfc	1	0	3	1	0
Dfb	1	0	1	3	1
Dfc	6	6	2	1	1
ET	1	1	1	0	0

Table 2. Aggregate Köppen – Geiger climate classification for 39 stations in Trentino according to several time windows and scenarios. Table cells contain the number of stations in each class. Legend: Type C:: rainy climates of middle latitudes, mild winters (microthermal).Type E: polar climates, no warm season. Subtype "f": no dry season. Subtype "a": hot summer. Subtype "b": cool summer. Subtype "c": cool and short summer. Subtype "T": "tundra-like" conditions. From Eccel et al., 2016

Vulnerabilities

Understanding the vulnerabilities of a territory is important to properly drive the actions to mitigate or to adapt to the effects they are provoking. Climate changes and microclimatic phenomena are stressing our cities, leading to important damages for people and ecosystems. Moreover, the intensity of the phenomena is increasing, due to socio-economic and demographic developments.[17]

Cities are the places where climate change impact are expected to be higher since they are exacerbated by the demographic composition of their quarters and by their activities as well as their urban design, leading to microclimatic phenomena like Urban Heat Island (UHI) and exposing them to an increased flood risk, due to high number of impervious surfaces.[18]

Several factors determine vulnerability rates (e.g. morphology, sewage infrastructure, green and blue infrastructure, deployment of human activities).

The simulation of minimum and maximum temperatures in Italy carried out by Zollo et al. (2016) (Figure 7) according to scenarios RCP4.5 and RCP8.5 projects an uniform warming between 2 and 3°C, with the former scenario. While using the former one, warming is significantly higher, with peaks of 6°C.

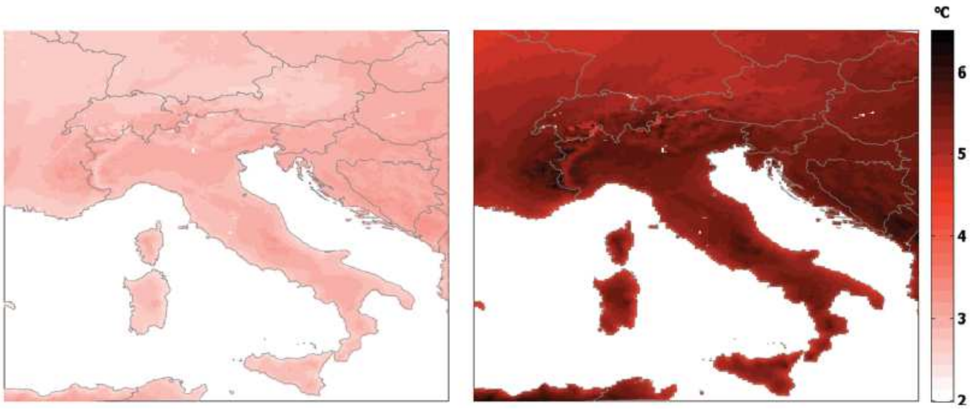


Figure 7. Climate change signal for the period 2071–2100 versus 1981–2010 for maximum temperature. IPCC scenarios: left "Rcp4.5", right "Rcp8.5". From Zollo et al. (2016).

A simulation of intense precipitation in Italy, with the same model premises (RCP 4.5 and RCP 8.5), leads to the result that, in the central Italian Alps, intense daily events are expected to increase only in the top end of the statistics of occurrence, that is, around absolute maxima (Figure 8). This is a direct consequence of the higher atmospheric dynamics brought about by higher temperatures. However, for less intense daily rainfall (like 90° percentile, that is, the 10% most rainy days in a year), these simulations do not predict an increased rain intensity.

[17] EEA(2012).Urban adaptation to climate change in Europe Challenges and opportunities for cities together with supportive national and European policies, EEA technical report 2/2012

[18] Ibidem

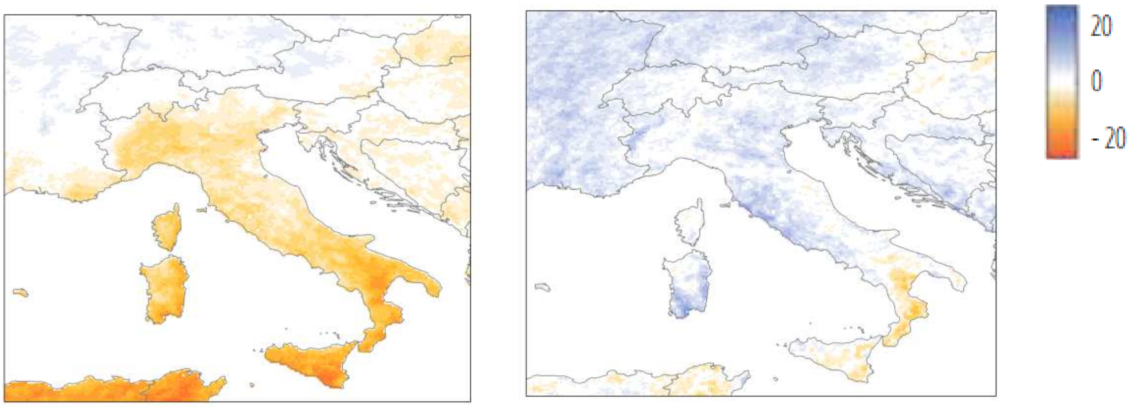


Figure 8. Expected change in daily precipitation for Italy,2041-2070 vs 1981-2010, IPCC scenario "Rcp4.5". a): 90th percentile. b): 99th percentile. From Rianna et al., 2015.

Considering IPCC7[19] and the European Reports, such as EEA (2016)[20], the main vulnerabilities cities are going to face can be considered heat waves, flooding, and water scarcity (droughts). Considering the morphology and the climatic trends of the town of Trento, this is true also for this town.

2.1 Heat waves

2.1.1 Urban heat island (UHI) in Trento

The UHI effect is one of the main microclimatic phenomena affecting our cities and it consists of higher values of surface air temperature occurring in the urban areas as compared to the surrounding rural ones.[21] The phenomenon is mainly caused by bi-dimensional and three-dimensional characteristics of the urban fabric, but it is also a consequence of human activities, such as transportation and heating or cooling systems.

As reported in the analysis of the urban thermal fingerprint by Giovannini et al. (2011)[22] the **diurnal intensity of the UHI of Trento is typically around 3°C**, but in certain conditions it can be higher than 6°C, **owing to site morphology and topography**.

The intensity of the phenomenon is assessed by the difference between air temperature in urban environment and in the surroundings. Its value varies during the day, being usually higher at night.

Comparing values of temperatures obtained from different stations (represented in Figure 9 and Table 3), the following considerations can be highlighted:

- mean temperature difference in the valley floor between the urban area and the rural one has values between 0.6°C e 1.1°C;
- mean temperature difference between valley floor and hill has values between 0.7°C in Laste and 1.5°C in Cognola;

[19] IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[20] EEA (2016). Urban adaptation to climate change in Europe. [online] Available at: http://www.eea.europa. eu/publications/urban-adaptation-2016 [Accessed 31 Jul. 2017].

[21] Petralli M., Brandani G., Massetti L., Orlandini S. (2014). L'uso del verde in ambiente urbano, in Pianificazione urbanistica e clima urbano. Manuale per la riduzione dei fenomeni di isola di calore urbano, a cura di F. Musco and L. Fregnolent (Il Poligrafo: Padova), p. 263-266.

[22] Giovannini L. et al.(2011). Analysis of the Urban Thermal Fingerprint of the City of Trento in the Alps, American Meteorological Society vol.50:1145- 1162, DOI: 10.1175/2010JAMC2613.1.

- compared to other cities, the heat island of Trento is not particularly high: maximum registered values of difference span from 2°C to 4°C, but in particular conditions they can reach values of 6°C.
- variation of temperatures and their variability during the day are not influenced only by morphology and topography but also by the meteorological phenomena such as cloud cover and wind. In fact, difference of temperature between urban and rural decreases with cloud cover, both during day and night, but with different entities in the different stations.

	All day			Daytime			Night time		
Station	N	ΔT_{u-r}	σ	N	ΔT_{u-r}	σ	N	ΔT_{u-r}	σ
Gardolo	53359	0.76	1.61	29415	0.03	1.30	23944	1.67	1.49
Roncafort	42704	1.07	1.50	23391	0.49	1.24	19313	1.79	1.47
Trento South	53304	0.58	1.35	29427	-0.06	1.03	23877	1.37	1.27
Cognola	52849	1.48	1.56	29153	0.74	1.47	23696	2.39	1.13
Laste	50288	0.65	1.07	27827	0.54	1.20	22461	0.79	0.88

Table 3. UHI average intensity of Trento, calculated during full day, daytime and night-time. N: sample numerosity. ΔTu-r difference urban – rural temperature. σ standard deviation. From Giovannini et al., 2011

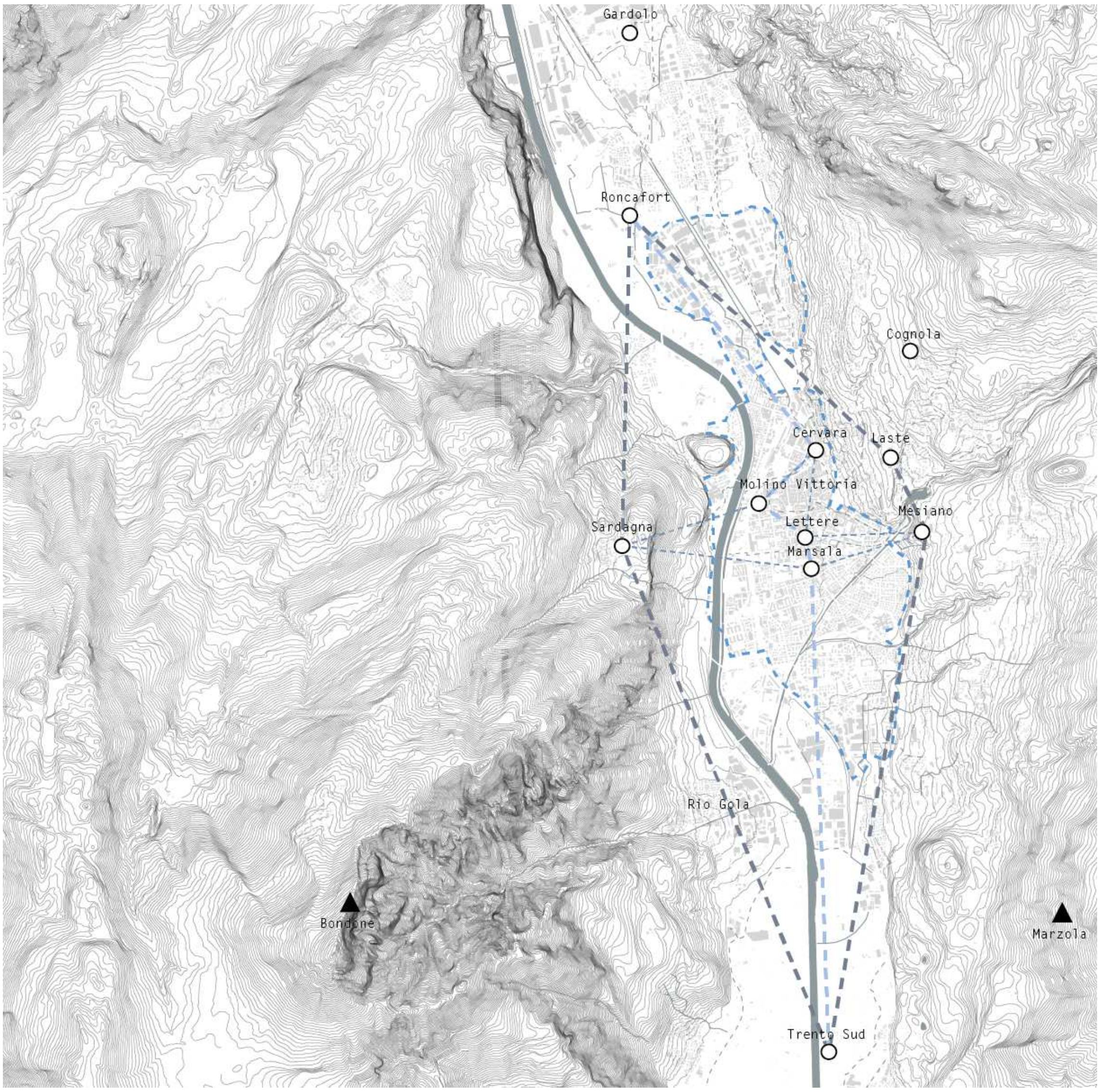


Figure 9. Location of meteorological stations used to evaluate intensity of UHI. Source: Giovannini et al., 2011.

Since town quarters have different temperatures, the temperature field can be described in terms of its constituent neighbourhood types using Local Climate Zones (LCZs), provided by Oke and Stewart (2012)[23], which is considered an appropriate classification method by Bechtel et al. (2015)[24]. The method identifies different urban landscapes related to the effect they produce in the urban temperature. They are defined by the type of surface (terrain roughness class, pervious surface fraction, albedo, surface admittance), morphology (aspect ratio, height) and human activities (traffic and heating). Since each city is characterized by different microclimates, it is relevant to understand which bi-dimensional and tri-dimensional properties are involved in energy exchanges.

The figure below (Figure 10) reports the classification of LCZs of the urban area of Trento.

[23] Stewart, I.D. and Oke, T.R. (2012). Local climate zones for urban temperatures studies, BAMS 93(12), p. 1879-1900, DOI: http://dx.doi.org/10.1175/BAMS-D-11-00019.1.

[24] Bechtel, B.,Alexander, P.J., Boehner, J., Ching, J., Conrad, O., Feddema, J., Mills, G., See, L. and Stewart, I. (2015), Mapping local climate zones for a worldwide database of the form and function of cities. ISPRS Int. J. Geo-Inf. 4, 199-219, doi:10.3390/ijgi4010199.

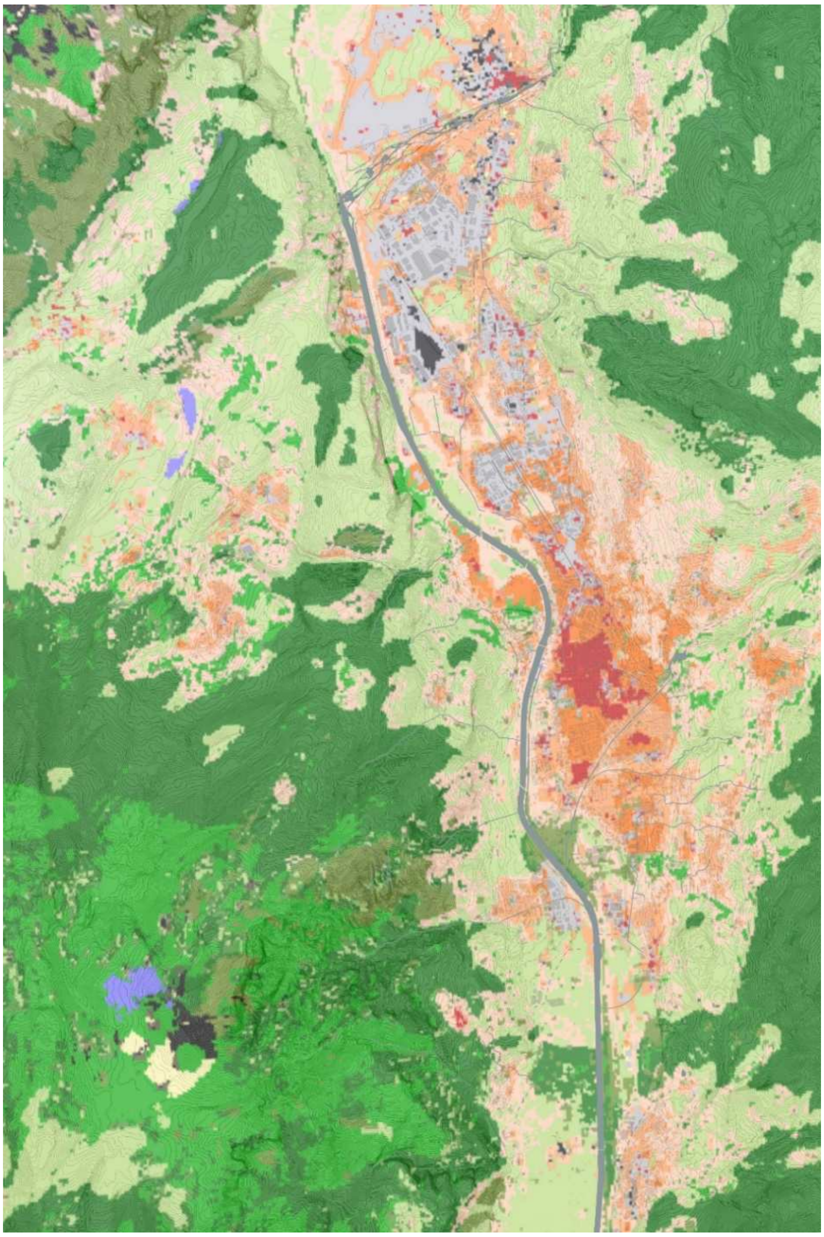


Figure 10. Mapping the constituent neighbourhood of Trento in terms of temperature, using the Local Climate Zones. Source: A. Codemo, Trento City microClimate Changes [Research thesis]

2.1.2 Green areas arrangement

Mapping of the existent green infrastructures (Figure 11) gives an idea of the UHI potential mitigation already provided by them[25]. Moreover, having a significant role in the economic, ecological and social aspects of urban life[26], the blue and green urban structure can be strengthened and developed in order to create more comfortable urban areas.

A green infrastructure, in fact, isn't only a mean that locally improves the microclimate, it is also **a framework that produces a full range of ecosystem services, useful for the mitigation to water, heat-related, and air quality problems.**

[25] Spirn A. W. (2013). Ecological urbanism: a framework for the design of resilient cities. In Resilience in Ecology and Urban Design, S. T. A. Pickett, M. L. Cadenasso, and B. P. McGrath, eds. (Springer Verlag).
[26] Gomez-Baggethun E. and Barton, D.N. (2013). Classifying and valuing ecosystem services for urban planning, Ecological Economics 86, p. 235–245, http://dx.doi.org/10.1016/j.ecolecon.2012.08.019.

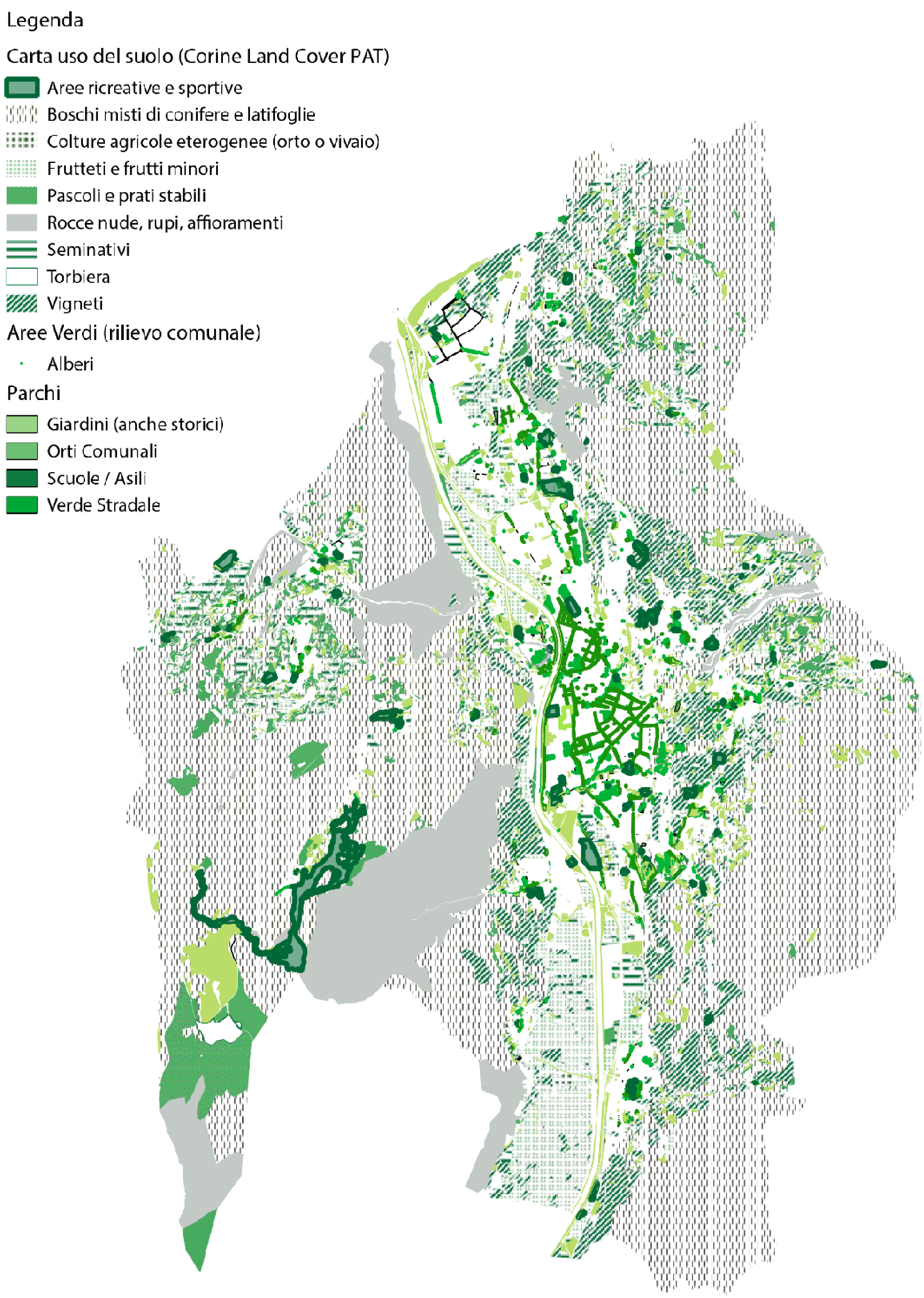


Figure 11. Mapping of Blue and Green Infrastructure of Trento. Source: Municipality of Trento

2.1.3 Impacts

Combination between present conditions and microclimatic phenomena with future predictions, suggests that heat waves is going to be one major seasonal problem in our cities. The European heatwave of the summer 2003 was estimated to have caused up to 70000 deaths in Central and Western Europe[27]. Climate change projections show a rise in the number of the heat-related deaths[28]. **Increasing temperatures and urban heat island effect have already brought to cases of morbidity and mortality increase in Italy**.

The risk connected to the increasing temperature can be divided between human and ecosystemic: on one hand, the human body is prone to a reduced capacity to thermoregulate causing feeble ailment (cramps, faints, bulge), but also more serious effects such as heat stress or heatstroke, which in particular conditions can lead to more dangerous health problems.[29]

Vulnerability of people is individual, but there are more frail sectors, due to their physiological conditions. They are the elderlies (over 65), the kids (under 5), chronic ill people, non-self-sufficient people and people who attend to physical activities outdoor. Moreover, socio-economic and behavioural factors have a great influence on the vulnerability. Factors such as gender, alcohol abuse, social isolation, homelessness, low income or poverty contribute to make people more sensitive to the impacts of high temperatures.

Besides the impacts on health, **a number of socio-economic and environmental impacts may result from higher temperatures and heat waves**, such as problems related to higher demand for cooling causing possible energy supply deficits, water supply (especially for agriculture), failure of services.

2.1.4 Heat-related risks

A possible assessment of the heat-related risk can be carried out by the method described by Morabito et al., 2015[30], which consists of a combination between normalization of exposure (density of population [inhabitants/km^2], Figure 13), natural risk (temperature [°C], Figure 12) and vulnerability (elderly density – aged over 65 - and children under 5 [inhabitants/km^2], Figure 14). The combination of these 3 indicators shows 5 different levels, which in the urban area of Trento vary between a level of medium and high risk (Figure 15). In particular, **three principal areas may have a high risk level**, so they are considered the ones with priority of intervention, since they are in the hottest part of the town and they have the highest density of population.

[27] EEA (2012). Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies. EEA technical report 2/2012.

[28] PESETA study projected almost 86000 additional deaths per year in 2071-2100 in the Eu-27 Member States

[29] Estate sicura come vincere il caldo, Consigli alla popolazione per affrontare le ondate di calore, Ministero della Salute

[30] Morabito et al.(2015), Urban-hazard risk analysis: mapping of heat related risks in the elderly in major Italian cities, PLoS ONE 10 (5).

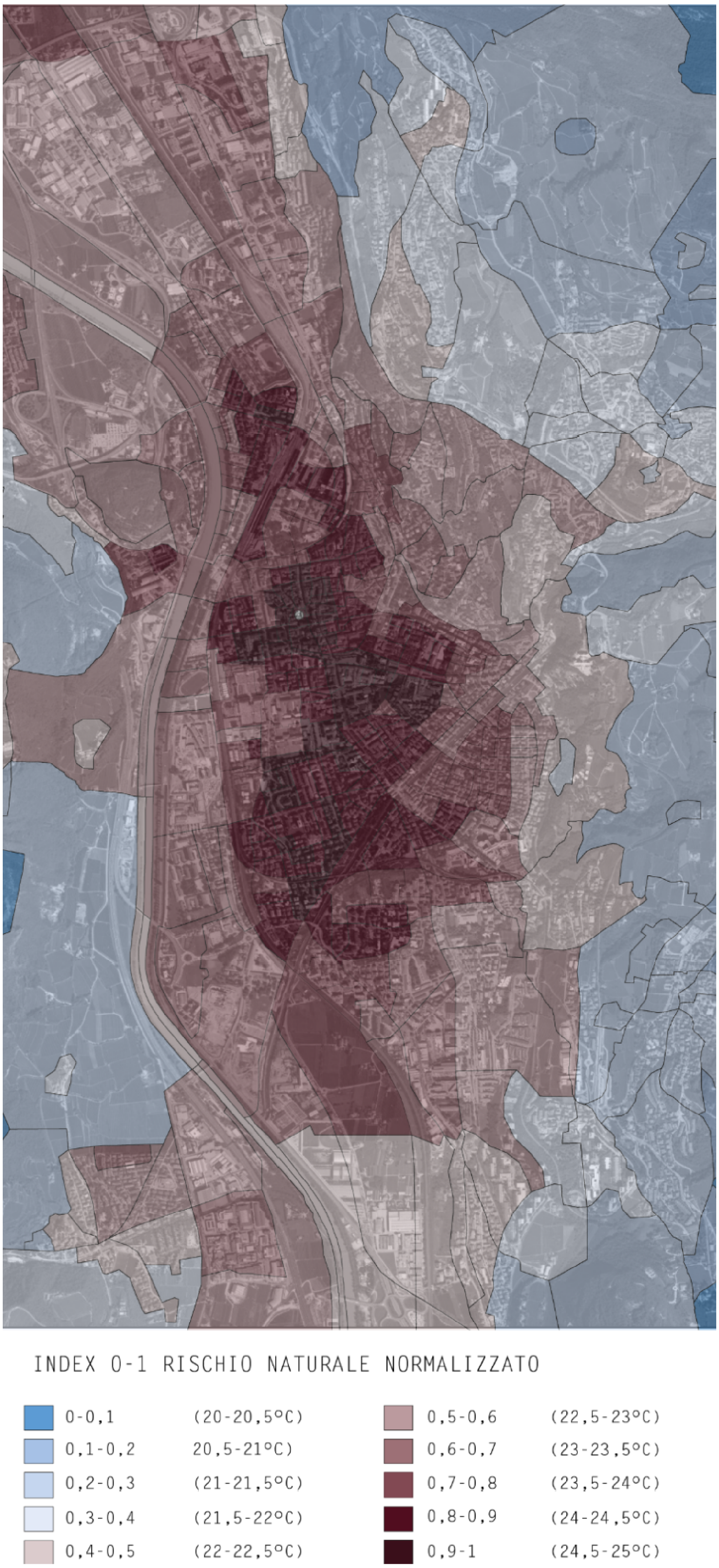


Figure 12. Air temperature of Trento. Source: A. Codemo, Trento City microClimate Changes [Research thesis]

Figure 13. Density of inhabitants of Trento. Source: A. Codemo, Trento City microClimate Changes [Research thesis]

Figure 14. Map of vulnerability of Trento: density of vulnerable inhabitants of Trento (under 5 years old and over 65 years old). Source: A. Codemo, Trento City microClimate Changes [Research thesis]

Figure 15. Heat related risk of Trento, calculated as the product of urban temperatures, density of inhabitants and density of vulnerable inhabitants. Source: A. Codemo, Trento City microClimate Changes [Research thesis]

2.2 Flood risk

Heavy rain events are the main cause of phenomena of flood, both flash and river ones, that in Europe in the last decades have significantly increased and caused substantial numbers of deaths and material damages.

Floods are a result from a combination between meteorological and hydrological extremes, but in most cases, they are also influenced by human factors which generally tend to aggravate the hazards by accentuating flood peaks.

The strongest flood risk in Trento is related to the overflowing of the river Adige in cases of extreme long precipitation events. Precipitation in the basin is on average decreased, but in the last period an increase of the frequency of extreme events is clear.[31]

The Province of Trento adopted the "Piano Generale di Utilizzazione delle Acque Pubbliche" (PGUAP) – General Plan of Water Usage, dealing with flood risk and also to define the instruments for guaranteeing safety.

2.2.1 Trento's water system

The most relevant water body in the area of Trento is the Adige river. It is the second longest river in Italy, with a basin of about 10.000 km^2 at Trento (Fig. 16 represents the water system of Trento). In the neighbourhood, its main tributaries are Avisio, north of the town, and Fersina, in its southern part. In Trentino, and north of it, the river regime is strongly affected by withdrawals, mainly for hydropower generation., both in the sub-basins and from the river itself.

Avisio river, also due to the morphologic and lithologic nature of its basin, represents perhaps the main concern for the vulnerability to floods in the northern quarters of the town. Fersina stream, flowing inside the town, was equipped with a strong riverbank system, to protect the southern part of the town from floodings.

Other relevant streams are Rio Gola, characterized by a very precipitous watershed, which, in case of extreme events, can cause debris flow in the urbanised areas south of the town; Rio Salé, whose basin is characterized by impervious terrains with low time of concentration, potentially leading to hydro-geologic risk (some southern quarters were flooded by Rio Salé during the catastrophic flood in 1966); Torrente Vela and Rio Valsorda are two other tributaries, the second entering Adige a few km south of the town.

Some artificial canals flow in the area of Trento: Rio Lavisotto, then called Adigetto, Fossa delle Bettine, Fossa Malvasia and Roggia Grande. In the north part of the town the canals where firstly constructed for the irrigation of fields, but eventually they started to serve as principal water collectors.

Connected to flood risk, aspects of both soil and water pollution have to be taken into account: in the system of engineered canals (the so-called "rogge") chemical pollutants above the allowed levels were observed, in the area of Campotrentino, in Rio Lavisotto and in the so-called Fossa Armanelli, probably related to the former industrial use of the areas. These collectors convey their waters into Adigetto, worsening its quality, also due to its low flow rates. Moreover, north Trento the purifier is located in a high-quality agricultural area (apple orchards)., setting up an attention element as a possible pollution source in case of flooding or accidental slurry leakage On the other hand, some areas well inside the urban tissue require a soil pollution remediation because of their former industrial use, such as the Carbochimica and SLOI areas, deeply polluted by lead for a thick soil layer.

[31] Portoni M. (a cura di), Progetto clima 2008, Previsioni e conseguenze dei cambiamenti climatici in Trentino, Provincia Autonoma di Trento 2008

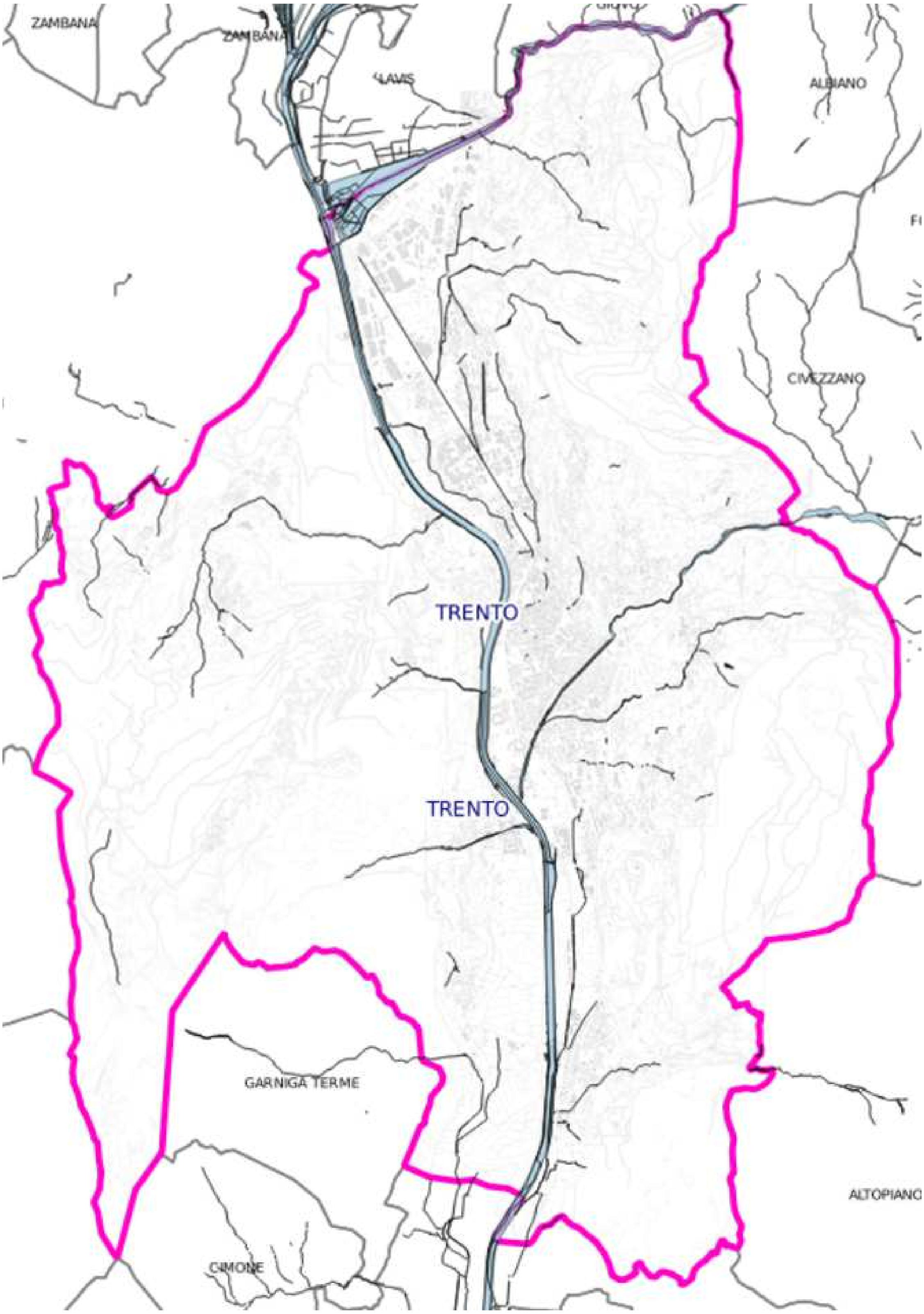


Figure 16. Map of the hydrological system of Trento. Source: Municipality of Trento

2.2.2 Terrain permeability and drain capacity

The decrease in surface perviousness caused by the urban expansion is a relevant aspect for a number of cities. In fact, it is strictly related to the hydrologic risk, reducing the infiltration capacity of the soil, which can alter water outflow regime. Such phenomenon may cause hydraulic problems and water pollution. A map of the permeability of surfaces (Figure 17) have been provided to give an idea of how permeability is distributed in the urban area of Trento.

Figure 17. Map of permeability of the surfaces of Trento, based on use of soil.

2.2.3 Impacts on cities

The impacts related to the hydrogeologic risk, particularly to flood, cause high economic losses since they include **damages to infrastructures, public and private properties, erosion or landslides**. Moreover, they include indirect losses such as interrupted power supply and the deterioration of groundwater quality caused by pollution. Finally, beyond possible **casualties and morbidity increase**, major events are responsible for more general impacts to the **socio-economic sector, namely to productivity, to services, to the job market**.[32] The most vulnerable subjects are elderlies, children, and generally people in poor health.

2.3 Water scarcity

Water scarcity is one of the negative effects produced by climate changes on water resources.

For this reason, a project was carried out to analyse effects on water flow rate and to improve monitoring unstable slopes in relation to hypothetical water losses from aqueducts, according to different meteorological scenarios, impacting not only on liquid flow rate, but also on the solid one, in particular with detritus flow.

Water scarcity and droughts are not exclusive of the drier areas of Europe: water resources are expected to decrease in Europe as a result of the increasing imbalance between water demand and water availability, so they can also occur due to high population density or as result of intensive agriculture or an increase in industrial demand.[33]

Water scarcity and droughts are two separated issues: the former consists of a long-term imbalance between demand and availability; while the latter refers to a temporary decrease in water availability; it can be distinguished between meteorological, hydrological or agricultural drought. Usually the primary cause of this phenomenon is rainfall deficiency; high temperatures can amplify duration or intensity of the phenomenon.

So far in the Province of Trentino there has been a good availability of quality water. Indeed, thanks to its abundance, until **recently little measures were taken to limit wastes**. In 2006 the local administration (Provincia Autonoma) adopted a plan to control water usage and to promote a saving approach.[34]

The analysis conducted on the first water balance approved with the Plan of water usage (PGUAP[35]) evidence that, even if the entity of the allowed withdrawal volumes is over the available ones, there is a balance between incoming and outcoming volumes. However, some failures cannot be avoided, in some periods and in particular areas, affecting human activities, with consequences on the environmental and on the ecosystems. In particular, is not rare the case of river regimes altered and other river dry for long periods.

Water quality indicators in a climate changing situation are water flow rate, temperature, and in case concentration of nutrients from anthropogenic activities.

A small decrease of water volumes can be expected for the period 2040-2070 in comparison to the reference period 1980-2010. An increase of volumes of available water is expected during winter, but with less snow (hence affecting spring water availability), while a remarkable decrease is expected in summer.

The clearest effect of climate change regards seasonality of the water cycle: hotter and drier summer are expected to lead to water scarcity, also considering an exacerbation of glacial retreat.

The expected changes in the annual cycle might require a change in water management and planning.

[32] EEA (2012). Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies. EEA technical report 2/2012.
[33] EEA (2012). Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies. EEA technical report 2/2012.
[34] Portoni M. (a cura di) (2008), Progetto clima 2008, Previsioni e conseguenze dei cambiamenti climatici in Trentino, Provincia Autonoma di Trento.
[35] Piano di Utilizzazione delle Acque Pubbliche

2.3.1 Impacts on cities

Sensitivity of people to water scarcity and droughts are in principle similar to those influencing sensitivity to heat and floods: they affect similar groups, such as elderlies, children and ill people. The socio-economic factor that influences most impacts is social imbalance.

As for the above-described vulnerabilities, **water scarcity and droughts influence economy, society and environment**: the main sectors that will be affected are public water supply, energy production, consistency of groundwater and surface water bodies.[36]

2.3.2 Water balance

The analysis on precipitation trends (Paragraph 1.3.1.2) shows a decrease in the last decades, particularly evident starting from 2003. **The water flow of river Adige is facing a contrast regarding consumers who use water all the year and those who need it only for short periods** (tourism and agriculture).

In fact, an important water contribution to the water balance in the basin comes from ice and snow melting in spring, responsible of the filling of the artificial reservoirs (for hydropower or, secondarily, for irrigation). The annual cycle of water flowing in the river reaches minimum values in late winter, and the maximum values in late autumn (Figure 18)[37].

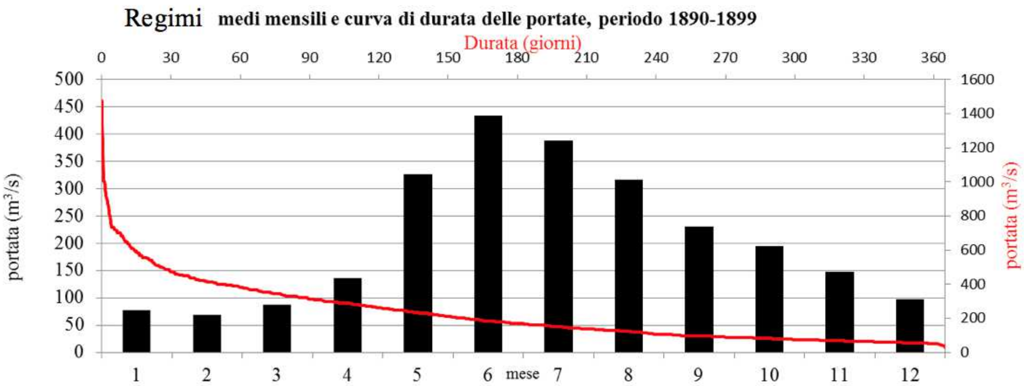


Figure 18. Monthly flow rates of Adige river at Trento (histogram). In red: duration curve (days, upper scale). Courtesy prof. R. Ranzi, University of Brescia.

In this context, agricultural irrigation contributes to possible soil deficit in summer. Man-made basins are useful for facing critical situations in summer, but, in periods with low precipitation, areas with an absent or poor connection to irrigation network can reach critical conditions. In fact, irrigation concessions (as peak rates) in some periods are not compatible with water availability.

Some hypotheses about future scenarios (Table 4) are proposed, due to the impacts of climate change on water cycle (ice volumes reduction, evapotranspiration increase, reduction of snow cover and duration).

Mean monthly volumes [Mm^3]						
	A	B	2005	2020	Δ[%]	Δ[Mm^3]
January	0.43	284	307	314	2%	6
February	-0.31	275	258	253	-2%	-5
March	-0.60	339	306	297	-3%	-9
April	-2.31	459	332	297	-10%	-35
May	-0.91	769	719	705	-2%	-14
June	-5.37	1115	819	739	-10%	-81
July	-2.67	910	763	723	-5%	-40

[36] EEA (2012). Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies. EEA technical report 2/2012.
[37] Quaderno sul bilancio idrico superficiale di primo livello. Bacino idrografico del fiume Adige.

August	-4.80	782	518	446	-14%	-72
September	-3.39	661	475	424	-11%	-51
October	1.44	518	597	619	4%	22
November	1.71	425	519	545	5%	26
December	0.27	332	346	350	1%	4
Total			**5960**	**5712**	**-4%**	**-248**

	J	F	M	A	M	J	J	A	S	O	N	D	Tot
Tot. Immitted volumes	307	255	287	319	718	842	738	535	476	585	634	375	6071
Tot. Immitted volumes (estimated 2020)	328	262	311	317	738	758	736	456	433	642	581	369	5931
Volumes for irrigation and antisalt	248	224	246	550	595	576	595	595	570	251	240	248	4939
Balance	59	31	41	-231	123	266	143	-60	-94	334	394	127	1131
Balance (estimated 2020)	**80**	**38**	**65**	**-233**	**143**	**182**	**141**	**-139**	**-137**	**391**	**341**	**121**	**992**

Table 4. Hypotheses of future scenarios of water cycle changes. Upper panel reports mean monthly volumes of water in the section of Trento registered in 2005, expected in 2020 and the calculation of percentage and absolute difference. Lower panel represents input volumes in the Veneto basin registered in 2005, the expected in 2020 and the calculation of balance. Source: "Quaderno sul bilancio idrico superficiale di primo livello bacino idrografico del fiume Adige".

The annual balance is positive, but there is also an evidence of increasing intensity of short critical events, especially in August and September.

2.4 Air quality related to higher temperatures

Climate change is expected to affect the future ozone concentrations due to changes in meteorological conditions. The increase of anticyclonic conditions at the same time enhances high irradiation (responsible for ozone formation) and pollution persistence in towns. If the link between meteorological factors and air quality is well known, on the other hand the quantification of ground-level ozone is still uncertain, considering the expected progressive reduction in the traffic pollution, the main source of chemical precursors for the ozone formation[38].

The increase of ozone concentrations due to future climate change is not expected to exceed 5 $\mu g/m^3$ by the middle of the century and it would therefore be outweighed by reductions in ozone levels prospected with the planned reduction of emissions. However, the synergic effect of exposure to both ozone and extreme heat is able to cancel off a possible reduction in ozone concentration in the future.

The main drivers are the concentrations of ozone precursors: NOX and volatile organic compounds (VOCs). NOX are products of the fuel combustion, for example in the urban area by road transport and industrial facilities, while VOC are emitted from various sources, including road transport, refineries and dry-cleaning. Moreover, biogenic VOC is emitted from vegetation and the quantity of release depends on the temperature.

[38] EEA (2015). Air pollution due to ozone: health impacts and effects of climate change. [online] Available at: https://www.eea.europa.eu/data-and-maps/indicators/air-pollution-by-ozone-2/assessment

For example, Methane (CH_4), a VOC, is released from coal mining, natural gas extraction and distribution, landfills, wastewater, ruminants, rice cultivation[39].

In general, summer anticyclonic persistence is associated with heat waves and may bring also higher levels of pollutants in the air if a breeze wind regime is not a climatic feature of the area. This has lead in Europe to frequent exceedance of the threshold values for health risks, worsening the higher rates of morbidity and mortality due to heat alone[40].

A reduction of NOX and VOC, which can cause serious damages to the human health, could be achieved as a twofold result of the adoption of the typical measures that can be taken in order to fight high temperatures: the promotion of a slow mobility, restrictions for road traffic, use of clean technologies for transport, heating and cooling systems, creation of green spaces that are capable of reducing temperatures and absorbing pollutants working as a filter, creating awareness and educating vulnerable groups[41].

2.4.1 Air quality of Trento

The area of Trento, laying in the valley floor, is exposed to the following pollutants: NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2, C_6H_6, Pb, B(a)P, As, Cd, Ni.

The monitoring network in the Province of Trento is composed of 7 permanent stations:

- 1 station in a traffic area (Trento - via Bolzano)

- 6 stations in the valley floor, 4 of which are in a urban or periurban area (Trento - Parco S. Chiara, Rovereto, Riva del Garda, Borgo Valsugana) and 1 in the rural area (Piana Rotaliana).

Routinely monitored pollutants are:

- PM_{10} and NO_2 in every station;

- $PM_{2.5}$ in the station of Trento – Parco S. Chiara, Rovereto and Borgo Valsugana;

- CO and C_6H_6 in Trento – Via Bolzano;

- O_3 in the 6 valley floor stations;

- SO_2 in Trento – S. Chiara

- Pb, B(a)P, As, Cd, Ni in Trento S. Chiara.

The following values refer to the annual report on air quality provided by the Province of Trento.[42] Values of pollutants are always under the legal thresholds, but in 2015 the value of SO_2 were at times over it in the station of Trento – Via Bolzano (traffic area). Moreover, in the year 2015 the "goal values" of PM2.5, arsenic, cadmium and nickel were respected, while those of O3 and benzopyrene were over the thresholds.

SO_2 is way under the limit, thanks to the reduction of use of fuels with concentration of sulphur.

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[39] EEA (2012). Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies. EEA technical report 2/2012

[40] EEA (2012). Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies. EEA technical report 2/2012

[41] EEA (2012). Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies. EEA technical report 2/2012

[42] http://www.appa.provincia.tn.it/binary/pat_appa_restyle/rapporti_annuali_aria/Rapporto_QA_2015.1475227283.pdf

PM_{10} is decreasing since 2006 and values are under the limit. The values of $PM_{2.5}$ are under the limit and also under the goals for 2020.

Concentrations of NO_2 are under the limit, only in 2008 values over the limit were registered but in a number of days under the limit provided by legislation. The annual mean of 2015 wasn't respected in the traffic-relevant station of Trento – Via Bolzano, while this was not the case in the other stations.

During 2015 sometimes values of O_3 above the threshold were registered, however they remained under the alarm limit; the goal value is still difficult to reach.

Values of lead are under the legislation level, while arsenic, cadmium and nickel are under the goal level. Finally, the value of benzopyrene in the station of Trento - Santa Chiara is a little over the goal value.

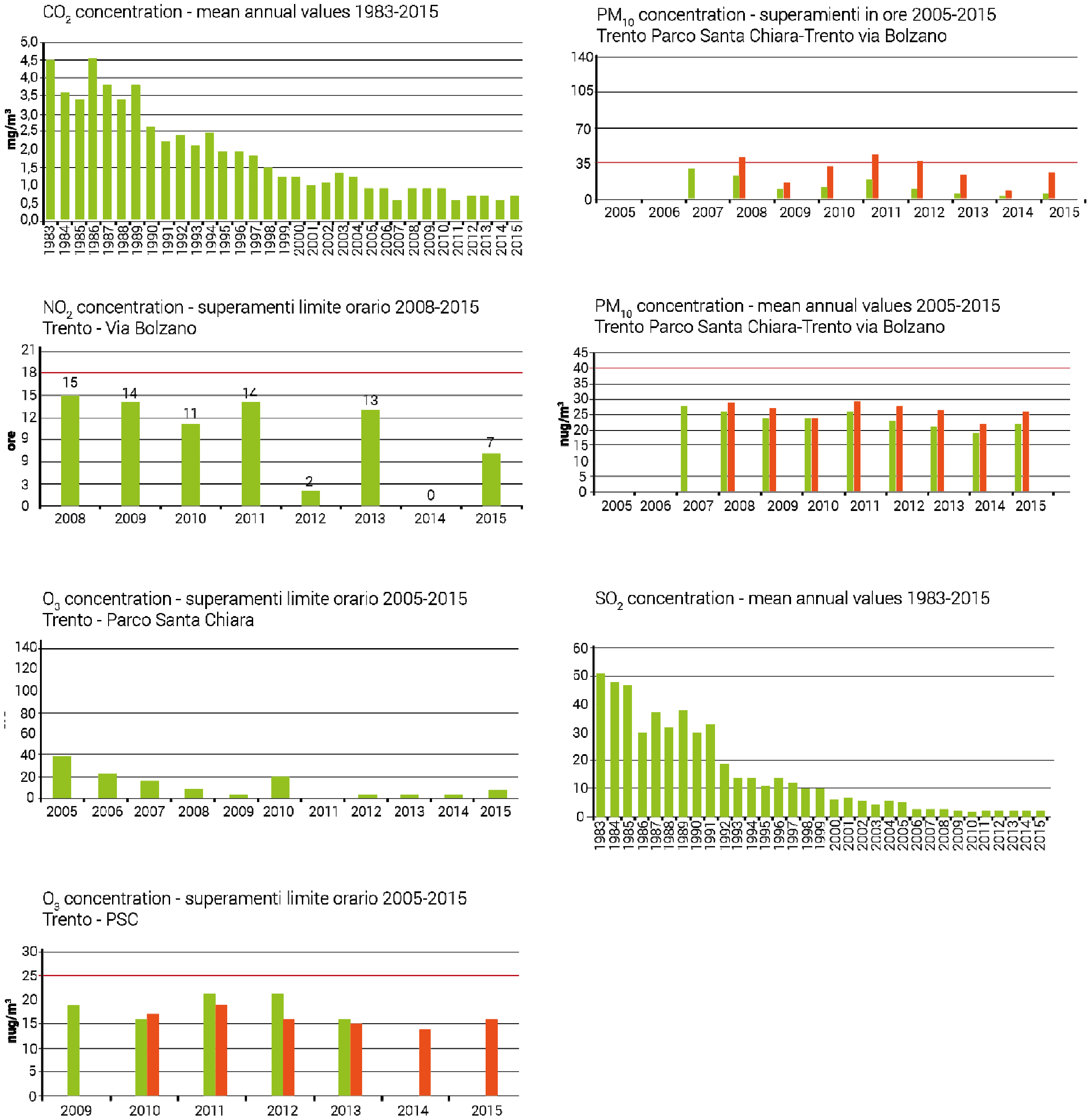


Figure 19. Pollutant concentration and threshold exceedance days in the town of Trento.

2.4.2 Impacts on cities

High levels of concentration of particulates and of ozone in the air may **increase the rate of mortality and morbidity**.

One of the impacts related to air quality is the infiltration of pollutants in the indoor environment, going inside homes, schools and other buildings. Poor air quality affects human health, causing negative impacts on the cardiovascular and respiratory systems. Moreover, higher pollen concentrations and longer pollen seasons increase allergic reactions and episodes of asthma.[43]

2.4.3 Risk level in Trento

To evaluate the level of risk related to air pollution, the risk response dose can be used. The following evaluation of impacts was carried out by the Province of Trento and is available on the site of the Provincial Agency for environment protection ("Agenzia Provinciale per la protezione dell'ambiente - APPA")[44]. The evaluation considers data of PM10 referring to 2010 and distributed in 6 stations located in the Province, in particular in Trento (2), Rovereto, Borgo Valsugana, Riva del Garda and Piana Rotaliana. All the data processed refer to the daily mean values of the 6 stations.

In 2010 the number of deaths related to PM_{10} was assessed; the rate in 2009 and 2010 is the same, lower than in 2008. The same trend regards the decreasing values of hospital admittances for cardiovascular and respiratory troubles related to PM_{10} exposition.

Limit value	2008	2009	2010
10	64 (54-74)	50(42-58)	50(42-57)
20	39(33-46)	27(22-31)	26(22-30)
30	24(20-28)	12(10-14)	12(10-14)
40	15(13-18)	4(3-5)	5(4-6)
50	10(9-12)	2(2-3)	2(2-3)

Limit Value	2010 Respiratory disease	2010 Cardiovascular disease
10	63(38-88)	130(78-193)
20	34(20-47)	69(41-103)
30	16(9-22)	32(19-48)
40	7(4-10)	14(8-21)
50	3(2-4)	6(4-9)

Table 5. Mortality rate due to PM10 and hospital admittance. Source: "Azienda provinciale per I servizi sanitari"

[43] Source: https://s3.amazonaws.com/climatehealth2016/low/ClimateHealth2016_ExecSummary_Standalone_small.pdf

[44] http://www.appa.provincia.tn.it/rapporto_ambiente_2016/

Mitigation

3.1 Definition of mitigation

The vulnerable sectors described above are already threatened – at the global level – by climate change: temperatures are rising, rainfall patterns are shifting, glaciers and snow are melting, and the mean sea level is rising. Most of the warming is very likely due to the observed increase in atmospheric greenhouse gas concentrations as a result of emissions from human activities.
Climate change mitigation are the interventions that humans can take to reduce emissions of greenhouse gases[45]; according to the United Nations Framework Convention on Climate Change (UNFCCC), the combination of mitigation and adaptation actions contribute to the *stabilization of greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (Art. 2 UNFCCC)*[46].

To mitigate climate change, we must reduce or prevent these emissions.

1. burning of fossil fuels (coal, oil and gas) in electricity generation, transport, industry and households (CO_2);
2. agriculture (CH_4) and land-use changes like deforestation (CO_2);
3. land filling of waste (CH_4);
4. use of industrial fluorinated gases.[47]

3.2 Ongoing policies

World

The international framework for greenhouse gas reduction is the Paris Agreement, signed at the end of the Conference of Parties (COP21), 2015. In brief, 195 countries, responsible for over 98% of GHG emissions, adopted the first-ever universal, legally binding global climate deal. The Paris Agreement entered into force on 4th November 2016.

The agreement sets out a global action plan to avoid dangerous climate change by limiting global warming to "well below" 2°C – and possibly to limit the increase to 1.5°C, since this would significantly reduce risks and the impacts of climate change.

[45] IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[46] Available at: http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf.

[47] Definition of EEA, https://www.eea.europa.eu/.

Before and during the Paris conference, countries submitted comprehensive national climate action plans (INDCs – Intended Nationally Determined Commitments). These have not been considered yet enough to keep global warming below 2°C, but the agreement traces the way to achieving this target.

Governments agreed to come together every 5 years to set more ambitious targets as required by science, to report to each other and the public on how well they are doing to implement their targets, and to track progress towards the long-term goal through a robust transparency and accountability system.

The agreement recognizes the role of non-Party (that is, non-national-governments) stakeholders in addressing climate change, including cities, other subnational authorities, civil society, the private sector and others. They are invited to:

- scale up their efforts and support actions to reduce emissions;
- build resilience and decrease vulnerability to the adverse effects of climate change;
- uphold and promote regional and international cooperation.

Europe

The EU has been at the forefront of international efforts towards a global climate deal. Following limited participation in the Kyoto Protocol and the lack of agreement in Copenhagen in 2009, the EU has been building a broad coalition of developed and developing countries in favour of high ambition that shaped the successful outcome of the Paris conference. The EU was the first major economy to submit its intended contribution to the new agreement in March 2015, on behalf of all its member states.

EU's Climate Action[48] has set the roadmap toward a "low carbon" society for year 2050. The 2030 climate and energy framework sets three key targets for that year:

- at least 40% cuts in greenhouse gas emissions (from 1990 levels);
- at least 27% share for renewable energy;
- at least 27% improvement in energy efficiency.

To achieve the at least 40% target:

- EU emissions trading system (ETS) sectors should be reformed and strengthened to cut emissions by 43% (compared to 2005);
- non-ETS sectors would need to cut emissions by 30% (compared to 2005) – this needs to be translated into individual binding targets for Member States.

Costs do not differ substantially from the costs of renewing an ageing energy system, necessary in any case. Total cost of the energy system in 2030 is projected to increase by an equivalent of 0.15% of the EU's GDP if targets are met cost-effectively. Overall there is a shift from operational costs (fuel) to capital costs (investments)

Average annual additional investments are projected to amount to €38 billion for the EU as a whole over the period 2011-30. Fuel savings will to a large extent compensate for these. More than half of the investments are needed in the residential and tertiary sectors.

EU's low-carbon economy roadmap suggests that in the long run (by 2050), Europe should cut greenhouse gas emissions to 80% below 1990 levels; milestones to achieve this are 40% emissions cuts by 2030 and 60% by 2040.

Italy

In Italy, the National Energy Strategy has been open to public observations until 31st August 2017; hence, this document is not yet officially in force. In the meantime, the Ministry for Environment is preparing the "National Climate-Energy Plan" - an EU's pledge - which will be presented in January 2018. The latter is not known in detail, but some hints have been disclosed about energetic efficiency: new energetic standards for new buildings, energetic renovation of public buildings, wider parameters for private building restoration, and more.

[48] All the following part excerpted from https://ec.europa.eu/clima/policies/strategies/2030_en

As well, all renewable energy production will be fiscally supported, and also in the field of sustainable mobility initiatives will be funded after agreements with local administrations.
Coming to the National Energy Strategy (SEN, Italian acronym), the roadmap described can be summarized as follows:

- fostering further renewable and low-emission energy sources;
- promoting energetic efficiency initiatives;
- sustain innovation policies to lower energy use.

Aiming to decarbonization, the main tool proposed by EU is the ETS system (Energy Trading System), even if this strategy is not boosting the expected switch from coal to gas yet. In any case, the phase out of coal-fueled power plants in Italy is expected within 2030.
Considering renewable energies, Italy has already attained in 2015 its scheduled goals for 2020 (17% of total consumption); for 2030, the target is 27%, organized as follows:

- Electric renewables at 48% – 50% (33,5% in 2015);

- Thermal renewables at 28% – 30% (19,2% in 2015);

- Transport renewables at 17% - 19% (6,4% in 2015).

More details can be sought in the Italian Government’s document (Italian Ministry of Economic Development, 2017).

Trentino

Similarly, to the national context, but in advance with respect to it, in 2013 the Autonomous Province of Trento issued its “Energetic and Environmental Plan for the Province” – PEAP (Provincia Autonoma di Trento, 2013), which is presently in force until 2020.

PEAP is inspired by the standards (“burden sharing”) imposed by the national government to meet the requirements arising from the EU’s engagement, mainly the goal of attaining a rate of 17% of renewable energy consumption.

At the beginning of its period of enforcement (2013) the PEAP envisaged a stable energy consumption rate in the following 10 years. The attainment of the target of 35.5% of “green energy“ used (according to the ”burden sharing”) is considered at hand, even if GHG production should be reduced to meet the long-term goals.

A strong reduction of GHG emissions from the civil sector is expected, until the end of the plan validity period. This is attributed to the continuous improvement – also as a consequence of the implementation of new standards - of the energetic efficiency of building envelopes.

An important item included in the local carbon balance is the growing intake from the forest.

The PEAP trusts the development of Smart Communities, also as a result of a joined effort from different smaller communities, as a means for tackling issues linked to the emerging social challenges, with a particular interest in network and cities managing.

The PEAP very shortly gives an outlook on the possible roadmap for the next period, recommending further actions on the building sector, aiming at making houses energy sources, instead of consumption sites, and increasing the development of biomasses and photovoltaic production.

3.3 Baseline emission inventory in the Province of Trento

The Baseline Emission Inventory (BEI) is a document that gives information about greenhouse gases of the municipality; it identifies the **quantity of emissions that has to be reduced and pinpoints critical situations and opportunities for a sustainable development**.

Trends of Emissions in the Province of Trento

Electrical Consumptions

Between 2000 and 2010 electrical consumptions increased by 22% with a maximum consumption in the civil sector, more specifically the tertiary sector increased by 65%, domestic by 25% and industrial decreased by 14%.

GWh	**Year**				
Sector	1990	1995	2000	2005	2010
Agriculture	53	52	52	51	68
Industry	1312	1331	1366	1609	1391
Tertiary	413	550	674	958	1090
Domestic	409	472	530	603	660
Total	**2188**	**2405**	**2622**	**3220**	**3210**

Table 6. Electric consumptions in GWh. Source APE- Piano Energetico Provinciale

Consumptions and emissions per sector

Buildings consumptions have been calculated with a greater detail, due to the importance that this sector has in the emission rate. The overall energy consumption has a value of about 180 kWh/m^2 and considering that a fraction of 25 kWh/m^2 of it is for production of sanitary hot water, the rest, about 155 kWh/m^2, is attribuible to warming systems. Between 2005 and 2010 consumptions of fossil fuels were stable.

Between 1990 and 2010 industrial energy consumptions decreased by 6%[49], while those for the transport sector increased by 24%, but between 2005 and 2010 they decreased by 13%. An evaluation of the emissions of CO_2 per each sector is reported in the followinf table (Tab. 6).

Sector	1990	2005	2006	2007	2008	2009	2010
Transportation	1294	1867	1867	1991	1857	1745	1621
Industry	779	572	572	559	583	578	587
Civil	866	1363	1238	1102	1141	1160	1172
Agricoltural	70	85	96	117	103	111	94
Total	**3009**	**3887**	**3773**	**3769**	**3684**	**3595**	**3474**

Table 7. CO_2 emissions per sector. Source: APE-Piano Energetico Provinciale

Renewables energies

Renewables energies cover 30% of consumptions of the Province of Trento (in 2010); this value is about 2 times higher than the national percentage. Production of green electric energy exceeds needs, while thermal renewables don't cover the requirements.

Moreover, Trento is the third town in Italy with the largest surface of solar thermal plants per inhabitant. Also photovoltaic surfaces in Trento, as well as in the entire Province, have a higher diffusion than in the rest of Italy.

[49] The decrease can be attribute to the economic crisis.

Emission inventory in 2006

Every municipality has interest in understanding energy consumptions and CO_2 emissions on its territory (Table 7 and Figure 20).

Emission factors considered follow the IPCC (2006) principles that consider CO_2 emissions of the territory consumed directly[50] and indirectly[51].

Sector	MWh/year	%
Public sector	32804	1,0%
Residential sector	1298644	37.9%
Tertiary	558431	16,3%
Public transportation	23897	0,7%
Private transportation	1508633	44,1%
Total	**3422409**	**100,0%**

Sector	tCO_2/year	%
Public sector	11957	1,3%
Residential sector	316453	33,3%
Tertiary	220248	23,2%
Public transportation	5891	0,6%
Private transportation	395451	41,6%
Total	**950000**	**100,0%**

Table 8. Quantification and percentages per sectors of energy consumptions and emissions relatives of the year 2006 in Trento.

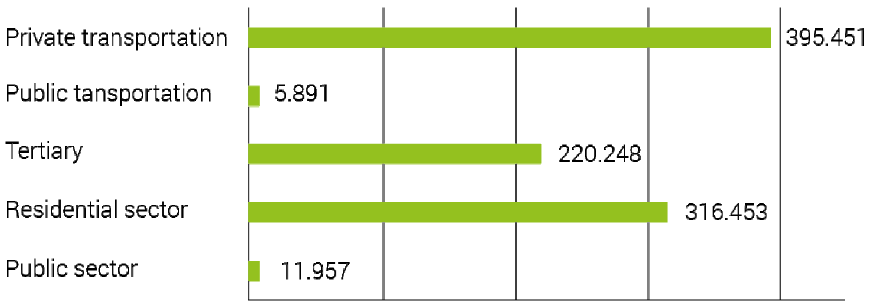


Figure 20. Graphic representation of CO_2 emissions per sector relatives of the year 2006.

[50] Fuel combustion of the local authorities

[51] Fuel combustion coming from use of electricity and heating/cooling systems in the areas of Municipality of Trento.

Emissions inventory in 2013

Trento registered a decrease of consumptions of about 11.3% compared to the reference year (2006) with a **decrease of emissions of 14.9%**. The sector of transports evidences a decrease of consumptions; more precisely, the private transports decreased their emissions, while the civil and industrial sectors registered an increase (as it is evident in Figure 21).

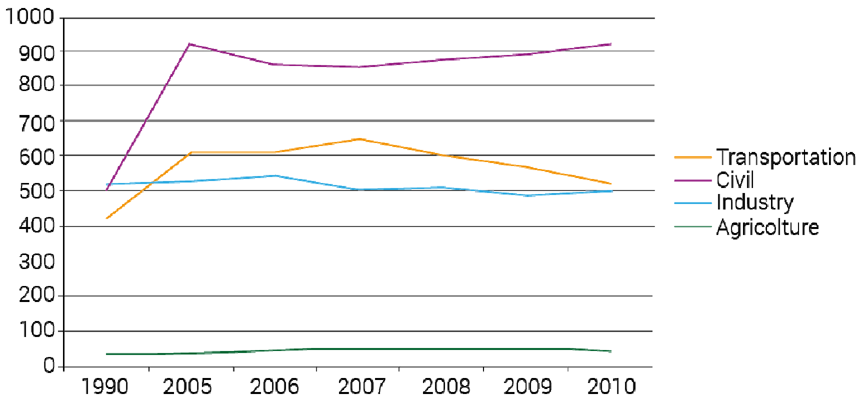


Figure 21. Graphic representation of the trends of CO_2 emission in the period 1990-2010 per sector.

An evaluation of the difference of energy consumptions between 2006 and 2013 have been provided by the Province of Trento and it is reported in the following figure (Figure 22) and table (Table 8).

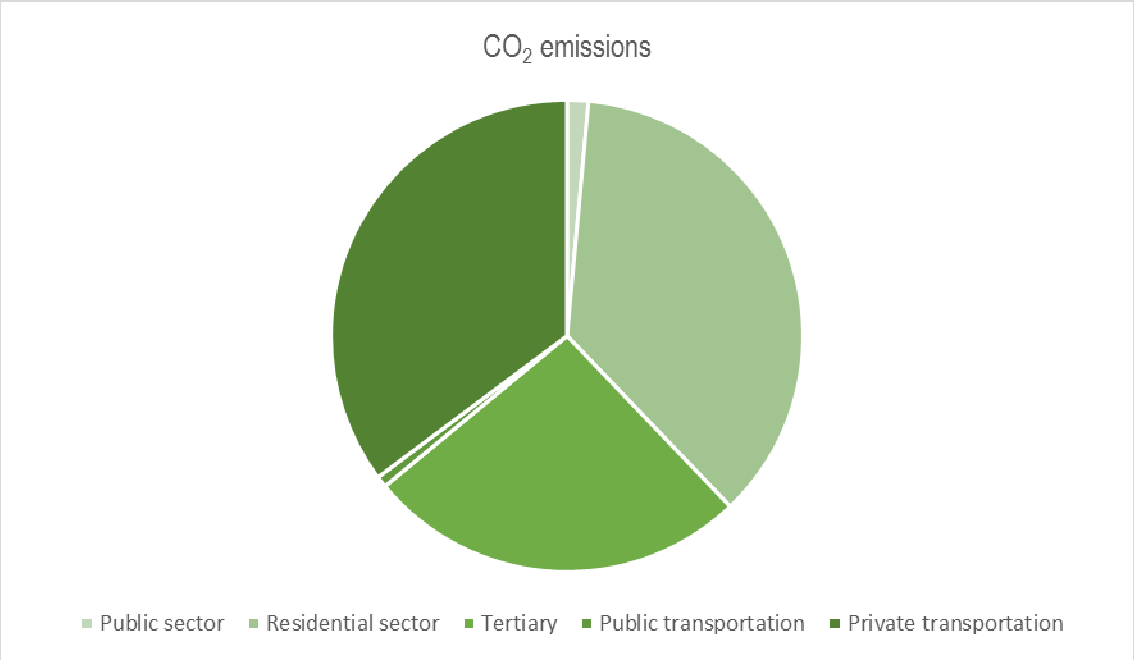


Figure 22. Graphic representation of percentages of CO_2 emissions in the year 2013 per sector.

Sector	MWh/year 2006	MWh/year 2013	Difference %
Public sector	32804	35273	7.5%
Residential sector	1298644	1264716	-2.6%
Tertiary	558431	575966	3.1%
Public Transportation	23897	25820	8.0%
Private transportation	1508633	1134625	-24,8%
Total	**3422409**	**3036400**	**-11,3%**

Table 9. Evaluation of difference of energy consumptions per sector between year 2006 and 2013.

Adaptation

4.1 Definition of adaptation

Impacts and vulnerabilities for ecosystems, economic sectors, and human health and well-being are happening and even if global efforts to reduce emissions prove effective, climate change is already a real concern, and adaptation actions, complementary to mitigation, are to be necessarily taken.
As for mitigation, strategies and actions are needed at the local, national, transnational and EU levels. In particular, **adaptation strategies** (e.g. technological measures, ecosystem-based measures, and measures addressing behavioural changes) **consist of integration of climate issues into other policy areas,** such as ecosystems and water management, damage risk reduction, coastal zone management, agriculture and rural development, health services, urban planning and regional development.
Adaptation is necessary not only to strengthen the resilience of environmental systems, but it also regards social and economic aspects, that are in serious danger due to extreme weather effects. So, adaptation measures aim at limiting the costs for reconstruction, preserving natural and human assets and at stimulating economic growth and at the same time enhancing a more sustainable and secure wellbeing.[52]

4.2 Ongoing policies

World

At the Paris climate conference (UNFCCC, COP21) in December 2015, all participating countries adopted the first-ever universal, legally binding global climate deal.
Even if the limit of a 2°C increase (of the average global surface temperature) is adhered to, many places on Earth will experience a higher temperature increase and climate change will still have impacts across the globe. Adaptation to climate change has thus been recognised within the UNFCCC as an important

[52] Definition from EEA, available at: https://www.eea.europa.eu/

policy pillar (with a primary focus on vulnerable developing countries), which is complementary to the mitigation of climate change.
The European Union and its Member States provide support to climate change adaptation in the developing countries within the United Nations Framework Convention on Climate change (UNFCCC). In particular, the adoption of the Cancun Adaptation Framework in 2010 has as primary objective to increase international cooperation to support developing countries and reduce their vulnerabilities, by the implementation of national adaptation plans, by establishing programmes on approaches to the effects of climate change and by establishing the Adaptation Committee as the overall advisory body to the COP through the proposition of draft recommendations.

Europe

The European strategy of adaptation of 2013 has three main objectives that have as main aim to make Europe more climate-resilient:

- Encouraging all cities of Member States to adopt adaptation strategies and proving funds to develop their adaptation capacities. Since 2015 it is possible to take part to the Covenant of Mayors initiative.
- Promoting adaptation strategies in vulnerable sectors such as agriculture, fisheries and cohesion policy with 'Climate-proofing' actions in order to make Europe's infrastructures more resilient.
- Improving knowledge about climate change and its effects in order to promote a better informed decision-making and developing the European climate adaptation platform (Climate-ADAPT).

Moreover, in the last years several projects have been developed in the wake of the European guidelines, implemented in local geographical contexts. The Municipalities of Trentino could be interested by the "Carta di Budoia", since the latter takes into account both the strategies adopted by the European Commission and those related to the Alpine context (e.g. decisions of the IX Alpine Convention in Alpbach and of the X Alpine Convention in Evian, "Linee Guida per l'adattamento ai Cambiamenti Climatici a Livello Locale nelle Alpi" in the XIII Conference in Turin). The agreement of "Carta di Budoia" is conceived for alpine municipalities and it aims to the adoption of local pilot actions.

Italy

As a Member State, Italy will take part in the European action to make the national territory more resilient to the effects of climate change, reducing its vulnerabilities in various sectors and territories.

The actions taken at the national level follow the guidelines of the European Policies, in particular on the environment safeguard, protection from natural disasters, sustainable management of natural resources and health safeguard.

Some projects that follow this direction are:

- "Strategia Nazionale per la Biodiversità"[53] and the documents for "Strategia per l'ambiente marino"[54] provided by Ministero dell'Ambiente e della Tutela del Territorio e del Mare (MATTM) in 2010, which consist in adapting measures in particular referring to the development of the community issue;
- "Sfide ed opportunità dello sviluppo rurale per la mitigazione e l'adattamento ai cambiamenti climatici"[55] by the Ministero delle Politiche Agricole Alimentari e Forestali (2011);
- "Linee guida per preparare piani di sorveglianza e risposta verso gli effetti sulla salute di ondate di calore anomalo"[56] issued by Ministero della Salute in 2006; and a National Plan to prevent from heat waves, which involves 34 cities. Moreover, in 27 cities Heat Health Watch Warning Systems and a system of mortality watch are available.

[53] Available at: http://www.isprambiente.gov.it/it/temi/biodiversita/documenti/strategia-nazionale-per-la-biodiversita/index
[54] Available at: http://www.strategiamarina.isprambiente.it/
[55] Available at: http://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/5799
[56] Available at: http://www.ministerosalute.it/imgs/C_17_pubblicazioni_984_allegato.pdf

Despite these projects, it is also necessary to adopt a strategic approach in various sectors in order to face the effects of climate changes and to implement and monitor them.

In this purpose, the "Strategia Nazionale di adattamento ai cambiamenti climatici" (SNAC) has been developed by MATTM to be implemented by "Piani di Azione Settoriali" that define timelines and instruments to be adopted.

In fact, the National Strategy of climate changes adaptation (SNAC) is based on 3 documents:

- Technical – scientific report "Stato delle conoscenze scientifiche su impatti, vulnerabilità ed adattamento ai cambiamenti climatici", that identifies vulnerabilities of the national territory, with a priority reference to management of water and risks connected to extreme events and multi-sector aspects such as the cost of impacts of climate change;
- Technical – legal report "Analisi della normativa per l'adattamento ai cambiamenti climatici: quadro comunitario e quadro nazionale", which identifies the existing instruments available to integrate adaptation in sectoral policies;
- "Elementi per una Strategia Nazionale di adattamento ai cambiamenti climatici" gives a national vision about how to face in the future the impacts of climate changes in multiple sectors and identifies vulnerabilities, actions to reduce risks and to increase resilience. Moreover, considering the cultural importance of the Italian territory, it tackles the issue of assessing possible vulnerabilities and damages to our cultural heritage.

Moreover, in the last years several projects have been developed in order to give directions and local strategies considering the European guidelines and the local geographical context. The Municipalities of Trentino could be interested by the "Carta di Budoia", since the mentioned document considers the strategies adopted by European Commission and the ones related to the Alpine context (e.g. decisions of the IX Alpine Convention in Alpbach and of the X Alpine Convention in Evian, "Linee Guida per l'adattamento ai Cambiamenti Climatici a Livello Locale nelle Alpi" in the XIII Conference in Turin). The agreement of "Carta di Budoia" is open to the alpine municipalities and it is related to the adoption of pilot actions at the local level.

Trento

The Municipality of Trento joined the Covenant of Mayors in April 2014 and shared the Strategic Program, of the European Commission to reduce emissions, known as "20-20-20". The Covenant of Mayors can be joined voluntarily and it is based on the commitment to the implementation of the EU's climate and energy objectives.

The vision that all cities share is to make them decarbonised and resilient, where citizens have access to secure, sustainable and affordable energy.

The role of the municipality is to guarantee interactions between different actors and to assure quality in decision-making. The first step of the process is the definition of the emissions made by the municipality: mobility has the greatest impact, while residential and tertiary together contribute for more than 55%.

4.3 Nature-based solutions / BGI approach

The European Commission defines **green infrastructure (GI)** as:

> ***a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services****. It incorporates green spaces (or blue if aquatic ecosystems are of interest) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings.* (EC,2013b)

Using Nature-based solution is a key policy to face the climate changes: in fact, it involves many ecosystem services and strategies to adapt to the climate changes, but it also helps the city to attain sustainability and it is economically convenient. Moreover, the provision of green infrastructure is a key policy response to help planners to protect and restore ecosystems, but also maintain and enhance them, in line with the goals of many European Commission policies. As a matter of facts, BGI solutions have low carbon and material footprint, they directly improve local microclimate, add value to properties, both aesthetic and economic and improve quality of air (Figure 23).[57]

RESULTING SYNERGY BENEFITS

Urban heat island effect reduced	Building envelope cheaper	Reduced noise and air pollution
Outdoor air evaporative cooling	Surface flood risk reduction	Better conditions for pedestrians
Buildings more comfortable	Higher property value	Socialising more intensive
Buildings using less energy	Humans healthier	Water management more effective

Figure 23. Multifunctional benefits of a tree. Source: Climate KIC – Green Blue Solutions.

The BGI approach is a successfully tested tool for providing ecological, economic and social benefits through natural solutions (EC, 2013b). Many recognise that bringing Nature Based Solutions into the city is a powerful remedy for alleviating urban pressures and achieving resilience to climate change.

The synergy between urban components and ecosystem services reveals the multifunctional nature of the elements and the interactions between different functions, as it is shown in Figure 24.[58] In fact, Nature Based Solutions appear to be a powerful remedy for responding to the urban pressures and at the same time achieving climate resilience. To achieve a successful transition to a sustainable and resilient city BGI solutions must be integrated in the urban tissue and have an integrated design, enhancing ecosystem services (an example of typological solutions is reported in Figure 25).

[57] Cohen-Schacham, E., G. Walters, C. Janzen, and S. Maginnis (2016), Nature based Solutions to Address Global Societal Challenges. IUCN, Gland, Switzerland.
[58] IUCN (2012), The IUCN Programme 2013-2016. IUCN, Gland, Switzerland.

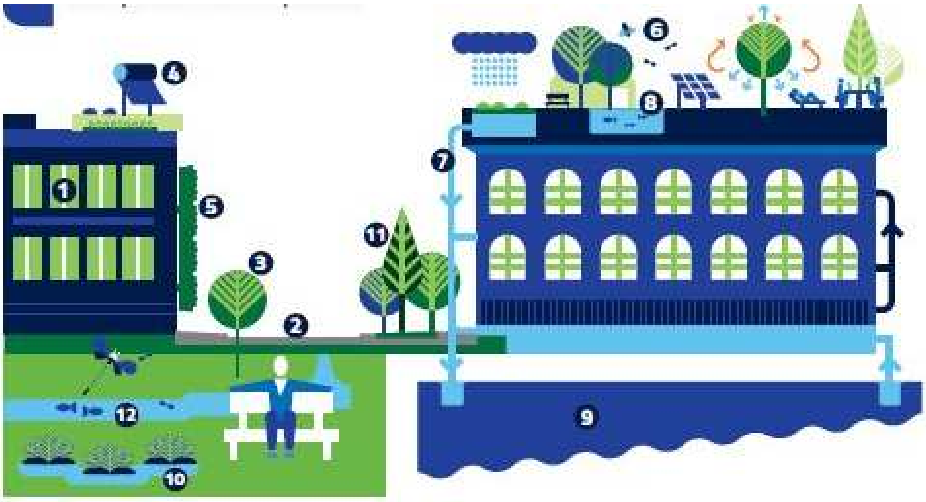


Figure 24. General section representing integration between BGI elements and urban components. Source: Climate KIC – Green Blue Solutions

Adaptation performance indicators

Heat stress[59]
Heat stress reduction can be achieved by provision of shade and evapotranspiration processes of vegetation or water surfaces. Moreover, also the colour of surfaces influences thermal radiation: dark surfaces (with low values of albedo[60]) absorb solar radiation and produce a temperature increase.

Evapotranspiration is influenced by air temperature, relative humidity, wind, and humidity of the soil (also related to soil properties).

Creation of shade has a great influence in the regulation of microclimate: it blocks direct solar radiation, it reduces heat entering buildings and it keeps soil cooler.

In other words, green and blue infrastructure elements can be enhanced and developed in order to reduce local temperatures; some of the measures that can be taken to mitigate the UHI effect are the following:

- Promoting green spaces, green walls and roofs;
- Integrating urban systems (such as infrastructures) with green elements;
- Creating shaded areas.

Hydrologic risk[61]
Prevention from hydrologic risk (floods) can be obtained through an effective storage of water, leading to peak flow reduction, since it impacts retention and drainage capacity of the catchment areas.

[59] Akbari, et al., Cooling Our Communities: A guidebook on tree planting and light coloured surfacing. Lawrence Berkeley Laboratory. US, EPA 1992
[60] Albedo indicates the quantity of solar radiation reflected back to atmosphere. In summer, a higher albedo produces direct benefits to the buildings or to soil surfaces but also to the surrounding environment.
[61] Measurable performance information based tools for co-creation of resilient, ecosystem-based urban plans with urban designers, decision-makers and stakeholders, Environ. Sci. Policy (2016), http://dx.doi.org/10.1016/j.envsci.2016.06.010

Thanks to the natural flood management we can reach flood protection but also other social, environmental and economic benefits. Measures related to the natural flood management are the following[62]:

- Restoring natural flows (re-connection of rivers with their floodplain);
- Restoration of wetlands, which can store flood water and help reducing run-off;
- Building of reservoirs in agricultural areas that can store flood water during extreme events;
- Promoting green spaces, green roofs and other sustainable urban drainage systems.

Scarcity of water[63]

Drought control requires groundwater recharge and inter-seasonal storage of water. In general, water scarcity can be contrasted by either decreasing the use of water, or increasing the supply. In this case, to mitigate this impact, it is important to work on grey measures such as on the water efficiency of buildings and of water-consuming activities in household, commercial business, industry and above all agriculture.

On the other hand, some green measures can be taken to improve the conservation of water:

- water storage in wetlands and water bodies
- maintenance and management of green areas
- use of plants that are adapted to water scarcity.

Air quality[64]

Urban vegetation can affect directly and indirectly local or regional air quality in four main ways:

- Reduction of temperatures and of adverse effects in urban microclimate;
- Removal of air pollutants;
- Absorption of toxic gases, such as carbon monoxide (CO) and volatile organic compounds (VOCs);

In particular, it can directly influence the presence of pollutants in the air, primarily by uptake via leaf stomata, though some gases are removed by the plant surface.

[62] http://ec.europa.eu/environment/water/flood_risk/better_options.htm

[63] EEA (2012). Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies. EEA technical report 2/2012.

[64] https://www.nrs.fs.fed.us/units/urban/local-resources/downloads/Tree_Air_Qual.pdf

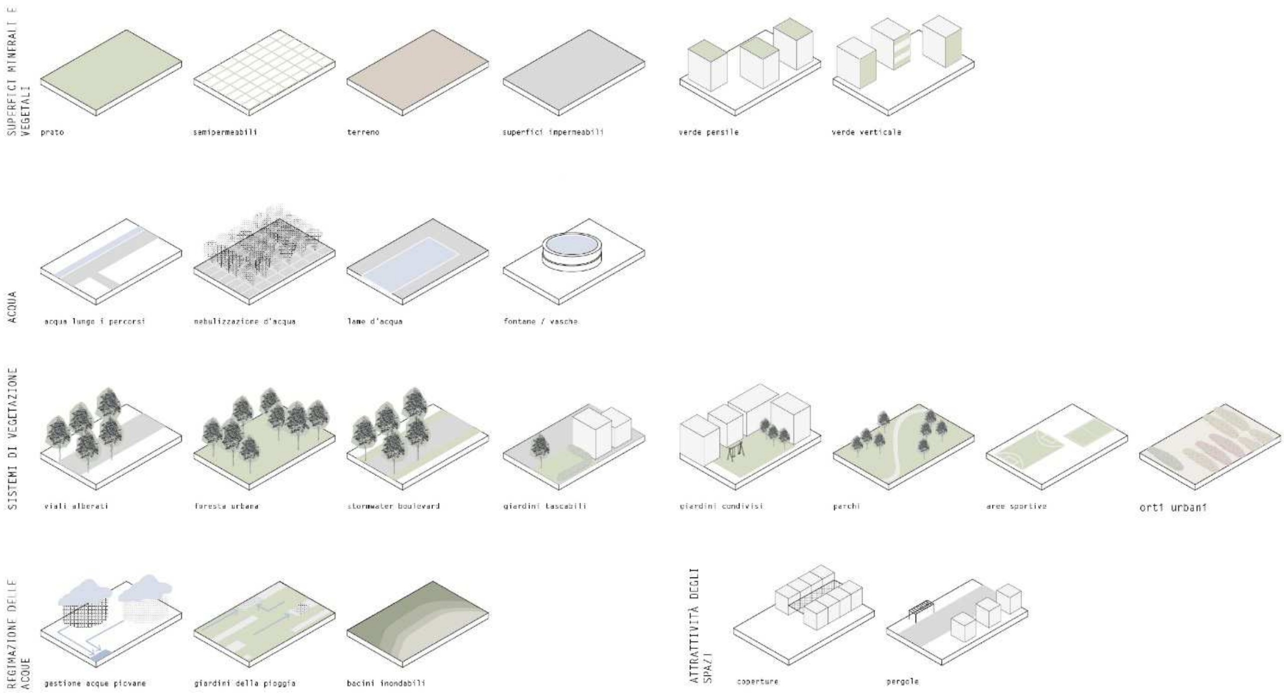


Figure 25. Types of Blue and Green solutions that can be applied in urban contests. Source: A. Codemo, Trento City microClimate Changes [Research thesis]

4.4 Multi-functional interactions (ecosystem services)

Nature-based solutions, as said before, are proven to bring multiple advantages in the adaptation to climate changes: some examples of impacts are reduction of water and air pollution, mitigation of flood risk and urban heat islands, increased resource efficiency, as well as provision of areas for recreation / amenity and urban agriculture (Figure 26). A key advantage of designing with NBS is that being vegetation-based, they have low energetic footprint and costs and they have many co-benefits if they are properly designed.

The challenge today is to **define strategies and actions that are capable of reaching multiple benefits**. A representation of the multiple interactions possible with the use of Nature-based solution is shown in Figure 27.

In the following paragraphs, we will report a general description of the principal benefits related to the use of the BGI Approach.[65]

65 Gomez-Baggethun E. and Barton, D.N. (2013). Classifying and valuing ecosystem services for urban planning, Ecological Economics 86, p. 235–245, http://dx.doi.org/10.1016/j.ecolecon.2012.08.019

Spirn A. W. (2013). Ecological urbanism: a framework for the design of resilient cities. In Resilience in Ecology and Urban Design, S. T. A. Pickett, M. L. Cadenasso, and B. P. McGrath, eds. (Springer Verlag).

Petralli M., Brandani G., Massetti L., Orlandini S. (2014). L'uso del verde in ambiente urbano, in Pianificazione urbanistica e clima urbano. Manuale per la riduzione dei fenomeni di isola di calore urbano, a cura di F. Musco and L. Fregnolent (Il Poligrafo: Padova), p. 263-266.

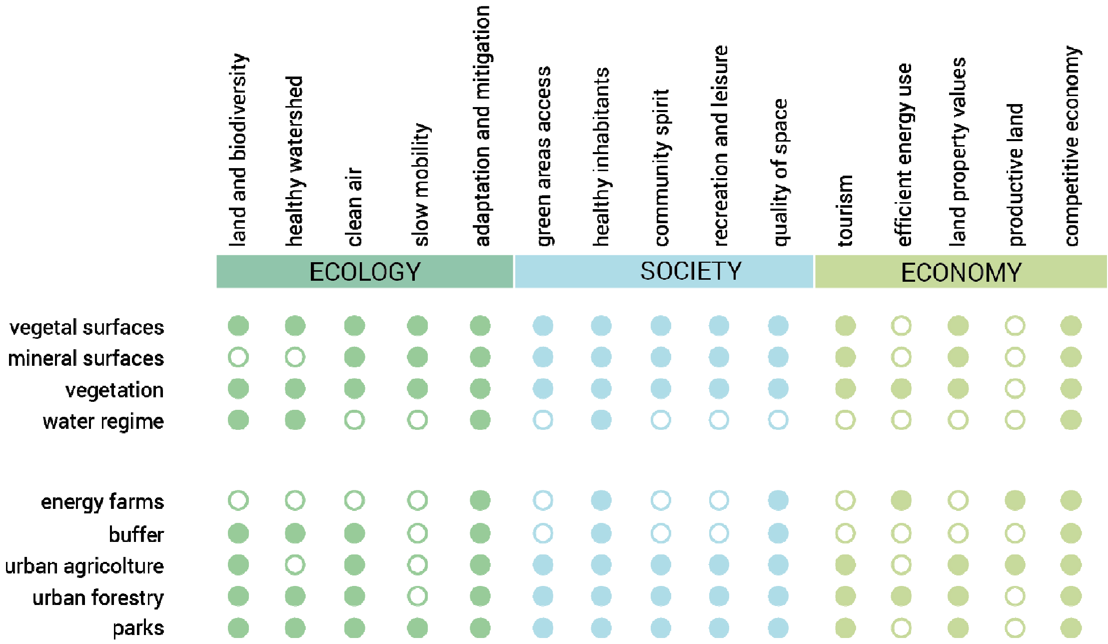


Figure 26. Representation of the benefits of some green and blue solutions.

Climate benefits

Green and blue structures are capable of regulating urban microclimate, in fact they have always been utilised to recreate comfort conditions indoor or outdoor.

The effects of BGI in the urban climate can be distinguished in two different scales, since they refer to two different processes: the urban scale (urban boundary layer and mesoscale) is affected by large green elements, e.g. natural parks and green belts and the local one (urban canopy layer), that is influenced also by minor green surfaces, e.g. green roofs, tree-lined roads, etc.[66]

Local effects are the result of two processes: shadow caused by trees and reduction of temperatures thanks to evapotranspiration. On the other hand, urban effects depend on various factors, such as winds, natural morphology, building morphology and they involve the process of evapotranspiration.

In fact, vegetation controls microclimate in different ways: foliage blocks direct solar radiation and lets diffuse radiation through. Moreover, vegetation regulates intensity and direction of wind and, thanks to processes of evaporation, it reduces air temperature. It is also capable of improving energy efficiency of the buildings and reducing the cost of energy supply, thanks to the production of shadow. Finally, since they store carbon dioxide, they have a general mitigation contribution.

As described in the paragraph of vulnerabilities, most of the surface treatments used in the cities are made of impervious materials, which worsens water drainage in case of heavy rainfall; on the contrary, the soil that covers the areas of green space is highly permeable; by soaking up water and recharging natural groundwater supplies, green space reduces the volume and rate of run-off and greatly contributes to a more sustainable urban drainage system.

Other benefits (economic, social, environmental, ecological)

Environmental benefits include mitigation of urban heat island, reduction of run-off, absorption of CO_2 and fixation of other pollutants, noise reduction, increase of biodiversity, etc.

[66] Oke T.R. (1988). Street design and urban canopy layer climate, Energy Buildings 11, p. 103-113.

Impervious surfaces reduce times of concentration, worsening flood risk in case of intense precipitation. Increasing green areas and permeable surfaces is a powerful solution to solve this problem.

Vegetation has the capacity of absorbing CO_2 (depending on species, environmental conditions, health of the plant). Moreover, since the use of plants reduces local temperatures in summer, a lower energy consumption is requested for cooling, which reduces use of fossil fuels. The correct use of vegetation contributes in reducing noise pollution of the urban traffic, which improves life quality (by decreasing sleep disturbs, stress).

Finally, vegetation contributes to safeguard biodiversity, usually at serious risk in the urban spaces. To do that, it is important to know what are the needs of fauna and flora, in order to design structures and systems that guarantee a suitable habitat.

Open spaces give a direct contribute to the city's economy, in fact they increase the quality of neighbourhoods and the value of buildings. The use of NBS contribute to increase the quality of open spaces, especially in case of abandoned or underused areas. Indicators that can be taken in consideration in the evaluation of economic improvement thanks to BGI are: efficient use of energy, competitive economy, increase of property value and productive land.

Social benefits regard a healthy life style, with the realisation of open recreational spaces and an incentivize to more sustainable means of transport.

Green spaces improve the aesthetic quality of the landscape and the way they are conceived by users, contributing to recreate a community atmosphere. Moreover, green areas contribute to the creation of spaces for urban agriculture, promoting equity and accessibility.[67]

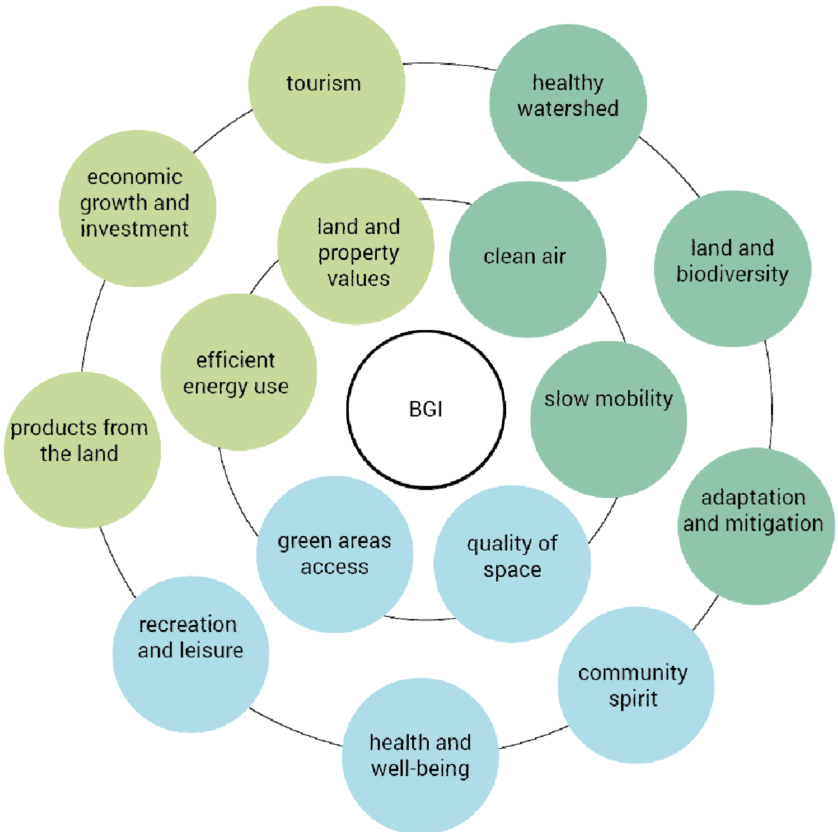


Figure 27. Multiple functions provided by green and blue infrastructure. (EEA, 2012)

[67] Report: Understanding the Contribution Parks and Green Spaces can make to Improving People's Lives.

Future scenarios for Trento

5.1 Urban climate goals

Objectives and types of actions

The objectives to be developed **to enhance climate change resilience consist in reducing vulnerabilities (to heat waves, floods, droughts)** and have the objective of enhancing both mitigation and adaptation.

Enhancing adaptive capacity decreases vulnerabilities of the cities and it includes several components such as knowledge and equity, access to technology and infrastructures, economic resources and effective institutions (EEA, 2012).

Adaptation to climate changes requests interventions that refer not only to designing spaces, but also to new types of sharing knowledge, to educate and make people more aware about these issues, e.g. as regards types of maintenance interventions, in order to make actions last in time, as well as to the instruments of governance, for introducing facilitation and funding tools for plan implementation.

Moreover, interventions and strategies adopted should involve all stakeholders: in this way every individual, corporation or administration could contribute to adaptation to a changing climate and improve the quality of urban spaces.

Firstly, it is fundamental that citizens, authorities and institutions understand the importance of adaptation strategies and the need to intervene: creating understanding and raising awareness of the impacts of climate-related phenomenon and possible solutions is essential. Providing knowledge on climate changes, impacts and adaptive and mitigation measures helps to successfully implement actions.

Secondly, technological resources are useful instruments to adopt for a better development of adaptive solutions and they can be undertaken by both public and private parties. Moreover, data related to infrastructures of the towns are conveniently dealt with by smart technologies. The correct operation of urban infrastructures is an indicator of its well-being.

Finally, economic resources and capital assets are important parts of the adaptive capacity, since they enable actors to plan and pay for adopted measures.

Referring to the vulnerabilities and the opportunities of Trento and comparing them with other realities in Europe, the following sectors are expected to be developed:

1. **Urban Planning**
2. **Governance**
3. **Education**

For the above-mentioned issues, the following strategies can be adopted:

1.1 - Incoming heat reduction
 - Stored heat reduction

1.2 - Pervious surfaces increase

1.3 - Water storage systems increase
 - Increase of water reuse systems

2 Reduction of anthropogenic contribution to energy balance
 - Promotion of slow mobility
 - Energy efficiency improvement

3 . Sensibilization programs
 - Actors' networking
 - Participation incentivization.

These objectives can be developed in concrete actions, measurable and so monitorable.

Also the European report EEA, 2016[68], considering the structure of most of European cities, suggests the main challenge of adaptation of existing buildings and infrastructures, including cultural heritage.

Climate change and urban challenges set the basis to rethink the city in its infrastructures, buildings, energy, water systems and drainage, sanitation, water management and mobility.

The following image (Figure 28) shows a matrix that connects the goals that the Municipality of Trento, like all the other cities, are requested to achieve and some of the devices it is possible to use in that particular urban context.

[68] EEA (2016). Urban adaptation to climate change in Europe. [online] Available at: http://www.eea.europa. eu/publications/urban-adaptation-2016 [Accessed 31 Jul. 2017].

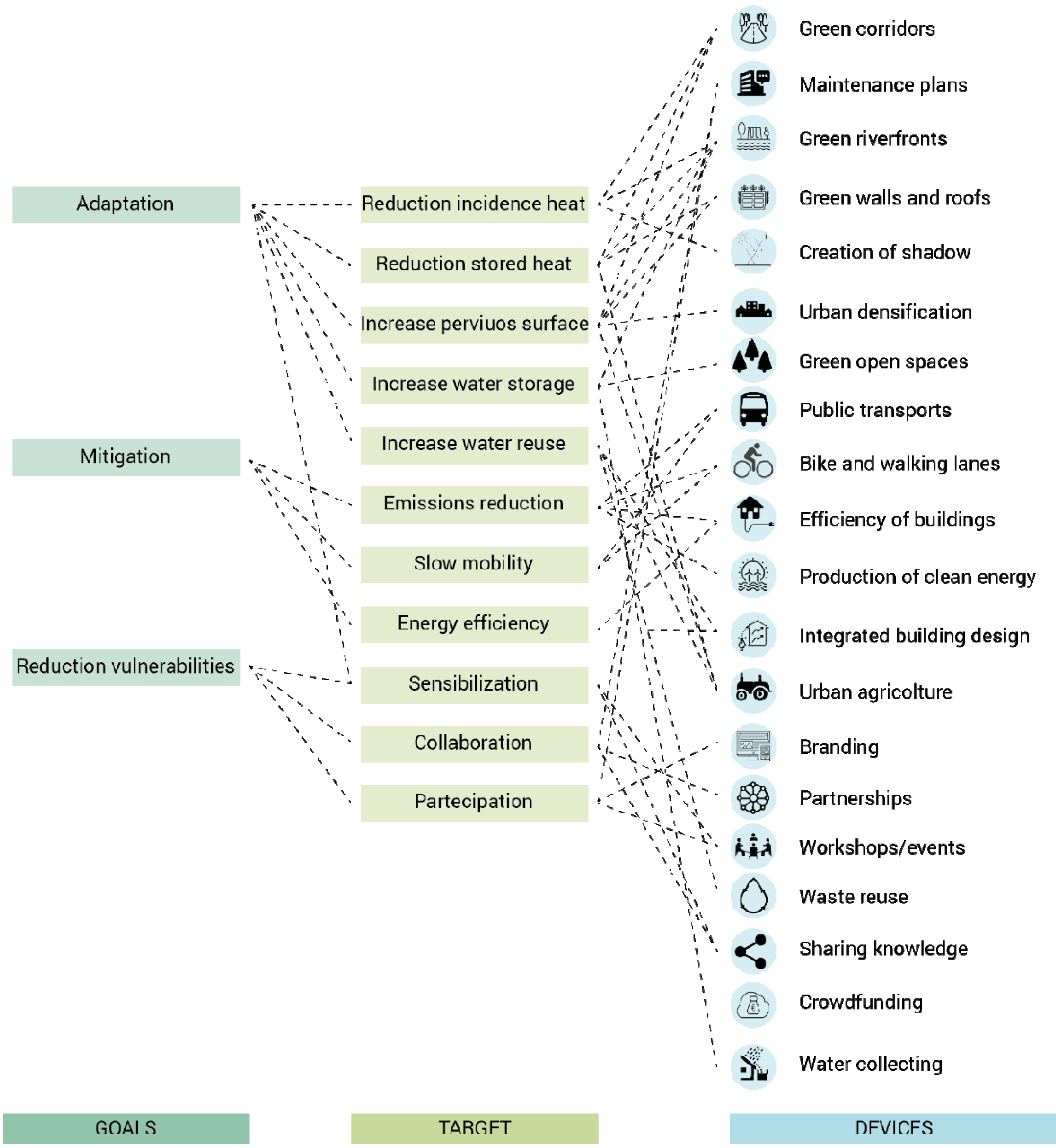


Figure 28. Matrix of goals of the urban challenge of Trento, target actions to develop the goals and the BGI-related devices.

Scaling results

The strategies that we can adopt can refer to multiple scales: global and national, regional, urban and local (district level).

As far as regional and global/national issues are concerned, one can consider the guidelines quoted in the above-mentioned paragraphs.

The entity of the contribution to climate resilience that a BGI element can give depends on the scale it is assessed. Some components can affect only the local microclimate, while others can contribute to the modification of urban climate.

At the urban scale, it is convenient to identify general strategies and actions to be implemented in order to accomplish the vision of the city, correcting the vulnerabilities and enhancing the opportunities present in the territory.

Cities may commit to ambitious climate and energy goals, but there is a gap between the definition of strategies and actions and the practical design and its implementation: the scale of the neighbourhood is perfect to bridge that gap. In fact adaptation decisions are context-specific and decisions are often taken at the local level.

Climate proof districts or Smart Sustainable Districts are an example of how to implement mitigation and adaptation strategies in a synergic structure: they are planned to be low carbon, efficient, accessible, smart-developed and attractive, thanks to an optimisation of the use of resources and responsive and clean technologies. The scale of the district is perfect to test and implement strategies and actions defined at the urban or upper scales, thanks to the possibility to design the urban components in practice. Moreover, the scale of the district is also convenient to test new ideas of partnership, financing models and community engagement that, at the urban scale, would remain vague and ill-defined.

At the local scale, elements that are considered very supportive for the climate change adaption policies are (EEA 2012):

- Good governance
- Presence of national programmes, facilitating local action
- Democratic and participatory institutions
- Cities' competences and authority to regulate climate-relevant issues
- Commitment of cities to take climate action
- Availability of economic resources, knowledge and information

Time phases: Building knowledge, Pilot actions, Implementation, Monitoring

As the actions and strategies proposed can refer to different types of actions, they can also refer to different application times: one of the main elements of an adaptation plan is the cyclic nature - and with dynamic features. In other words, the construction of an iterative structure is necessary, where the outcomes of one stage lead into the next. [69]

To be more specific, one solution is the Urban Adaptation Support Tool (Urban AST), which provides guidance on how to approach urban adaptation in a cyclic way. It consists of six regularly repeating steps, from analysis of vulnerabilities to the monitoring of the plan.

In fact, planning adaptation includes defining how different adaptation measures can best complement each other as well as the right timing and sequence for implementing them.[70]

For the case of Trento, a cyclic structure has been conceived that refers to the particular conditions of the town and that can be developed in 6 steps, described below (Fig. 29).

Preparatory and knowledge activities:

1. Profile and instruments: it is necessary to create awareness and improve knowledge about climate issues and solutions of mitigation and adaptation to make it work. The knowledge requested is at scientific, technical and local level and in systemic and long-term planning, as well as in dealing with uncertainties and to develop and support transformational adaptation.
2. Priorities: it is important to define priorities of interventions in order to make clear and well-planned actions. The priorities could be given by the level of risk of certain areas, but also by the easiness in implementing projects there.

[69] EEA (2016). Urban adaptation to climate change in Europe. [online] Available at: http://www.eea.europa. eu/publications/urban-adaptation-2016 [Accessed 31 Jul. 2017].
[70] ibidem

Designing new solutions:

3. Visioning: the strategies adopted to mitigate and adapt to the climate changes can lead Trento to the improvement of urban quality. As they are considered not only a problem that every city has to face, but also an opportunity to make it better. Visioning scenarios for the future of Trento is important since it helps to implement the proposed actions and increases the possibility to benefit from multiple services thanks to the integration of solutions between different issues.
4. Pilot actions: clear and well-defined actions make plan implementation simpler. They should be an integration between adaptive measures and innovative solutions in urban spaces.

Management and maintenance activities:

5. Implementation: this step relates to the development of an implementation plan, which is necessary for the enforcement of mitigation and adaptation actions. This step is strongly influenced by the existing procedures and policies, since it is characterized by the definition of objectives, deadlines and responsibilities.
6. Monitoring: the final step of the cyclic process is the determination of the impacts of implementation of the action on the urban climate. Moreover, it identifies if there are other necessities and if the plans and actions of mitigation and adaptation are being maintained.

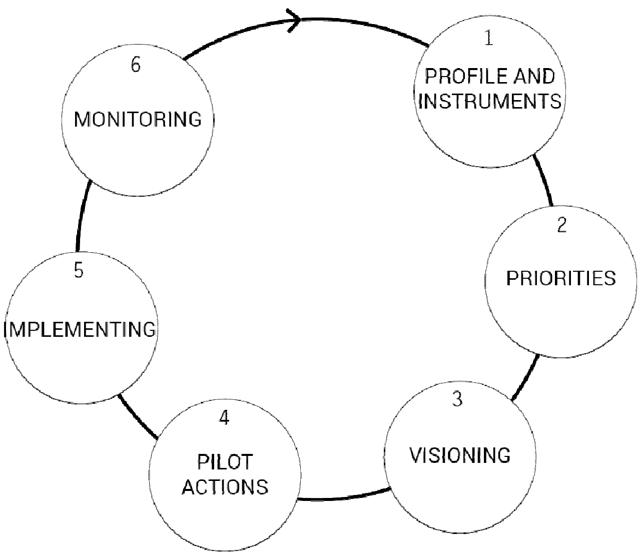


Figure 29. Cyclic structure conceived for the implementation of climate solutions of Trento. Source: A. Codemo, Trento City microClimate Changes [Research thesis]

5.2 Implementation of ongoing projects

EnRoute

EnRoute (Enhancing Resilience of Urban Ecosystems through Green Infrastructure) is a two-year project (Dec. 2016 to Nov. 2018) and the follow up of the MAES (Mapping and Assessing of Ecosystems and their Services) Urban Pilot, which seeks to enhance citizens' health and climate changes adaptation. The Urban Pilot delivered a report to support cities and in particular their policies, assessment and monitoring of urban GI and urban ecosystems.[71]

EnRoute seeks to further develop and enhance the quality of the framework of the URBAN MAES, to further investigate on the gap between the suitability of the MAES and its understanding at the local level; networking and improving knowledge and information, in order to increase people's awareness, are

[71] Technical report by the Joint Research Centre: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106443/enrouteinceptionreportfinal.pdf

project's scopes. In this way, it aims to promote the application of the urban green infrastructure elements at the local level.

EnRoute is a project funded by the Joint Research Centre of the European Commission which comprehends 21 cities, including Trento.

The project consists of three tasks:

- Task 1: Operationalisation of the URBAN MAES-framework
- Task 2: Science-policy interface on urban green infrastructures
- Task 3: Networking and improving flows of knowledge and information.

Los_Dama!

Landscape and Open Space Development in Alpine Metropolitan Areas LOS_DAMA! Is an European project within the program "Interreg-Alpine Space" and it is located in the axis Priority 3. Its main aim is to evaluate the Alpine natural and cultural heritage in a sustainable way, through comprehension, management and development of Alpine periurban areas as a fundamental part of the green infrastructure in order to enhance attractiveness and liveability.[72]

LOS_DAMA! is a 3-year project (Nov. 2016 to Nov. 2019) and connects various partners from Europe (Germany, France, Austria, Italy, Slovenia).

The project follows macroregional strategies of the development of EUSALP (Axis 7: development of ecological connectivity) and aims to strengthen the objectives of European Convention of Landscape.

The main aims of the project are:

- Cooperation: creation of a multilevel network of actors;
- Responsibility: create cooperation between municipalities and regional/metropolitan authorities to obtain the signature of an agreement with recommendations and strategies;
- Concrete actions: definition and selection of the initiatives to implement metropolitan policies.

The project seeks to define participatory processes in order to involve inhabitants and stakeholders and improve the knowledge and the activities to protect, develop, manage and evaluate periurban landscapes of the urban areas, also strengthening Alpine cultural heritage.

In particular, the city of Trento aims to develop the theme of re-stitching the town and the big green periurban areas through the axis created by the river Adige and connecting urban areas. In this way it would be possible to reconsider riverbanks, urban forest and urban agriculture as well as abandoned spaces that can be regenerated.

Stardust

Stardust is a project under the European program Horizon 2020, which aims to develop an integrated urban model for smart cities. It is based on a replicability approach, implementing issues of energy-saving, regeneration, smart services for the town, and improvement of life quality

The object of Stardust is the energetic recovery of Madonna Bianca quarter's "towers": the buildings will be renovated with thermal insulation, solar panels, geothermal heating and a program of education and participation of inhabitants. Moreover, Stardust will fit in the e-mobility program with actions aiming to incentivize electric mobility.

[72] http://www.comune.trento.it/Aree-tematiche/Ambiente-e-territorio/Parchi-e-giardini/Iniziative/LOS_DAMA and http://www.alpine-space.eu/projects/los_dama/en/home

Smart city Lab in Vela

The project “Smart city Lab in Vela” consists in a collaboration between the Municipality of Trento and the Fondazione Bruno Kessler (Trento), to test innovative solutions in a definite area of Trento, the hamlet of Vela.

The main project activities are the installation of instruments and infrastructures, monitoring and applications useful for both the municipality and the inhabitants, the realisation of ICT solutions for the inhabitants, and the promotion of activities that strengthen the spirit of innovation and experimentation through community’s participation.

5.3 Goal-Driven Planning Matrix

Some of the goals requested with the urban challenge have already been considered in the other projects described above. The following matrix resumes goals and targets for each project (Figure 30).

		Covenant	EnRoute	IEEE Smart City	EC
GOALS	Enhancement citizens's heath		●	●	●
	Adaptation to climate change	●	●	●	●
	Increase knowledge		●	●	●
	Sustainability			●	●
TARGET ACTIONS	Partecipation		●	●	●
	Developing GI		●		●
	Science/Policy interface		●		●
	Mapping		●		●
	Create a network		●		●
	Indicators to evaluate			●	●
	Education		●	●	●
	sensibilisation		●	●	●
	trained staff				●
	Internationalization			●	●
	Mobility Efficiency	●		●	●
	Optimisation use resources			●	●
	Energy efficiency		●	●	●
	Renewable energies			●	●
	Energy management			●	●
	Maintenance plans				●
	Reuse of waste				●
	Comparing cities				●
	Reducing land use			●	●

Figure 30. Matrix of the goals and target action of the ongoing projects in Trento and the suggested actions proposed by European Commission to enreach climate goals.

5.4 Future scenarios

The strategy of Trento to become a smart city is related to the promotion of social inclusion, to the adaptation to the majority of citizen's needs, to the digital alphabetization of its inhabitants. In this way, the role of innovation is fundamental **to define smart strategies that are adaptable and adaptive to changes**.
The vision of the smart city of Trento is based on three main objectives:

Development model based on high knowledge. The mentioned scenario regards reproduction, accumulation and dissemination of knowledge, competences and human capital.

Local identity. Trento seeks to maintain a continuity between past, present and future, recovering past vocations that are based on the values of a town with a great history, of an alpine town related to its territory and with an agricultural heritage, but in the same time also in relation with the world. In other words, Trento is a historical city, an alpine city and a city that seeks dialog.

Sustainability. Trento gives centrality also to the concept of sustainability, which is connected to the fragility (social and environmental) of urban ecosystems and to the issue of guaranteeing the same amount of resources that are now available also in long-term future.

The vision of the town of Trento is of a town of knowledge. The mentioned processes cause moments of reflection on the aspirations and the possible vocations of the town. Moreover, they cause an interrogation about localization of functions related to the development of education, research and innovation. Finally, they bring out the issue related to the adaptation capacity strengthening, to reach an increasing number of people.

Key words related to the smart vision of the town can be summarized as follows:

Innovation. The town will promote innovation activities, in order to reach changes and to be the creator of changes.

Internationalisation. Trento wants to be attractive, visible and cooperative in the world, in order to strengthen tourism, investments, human resources and in order to be recognizable in the world.

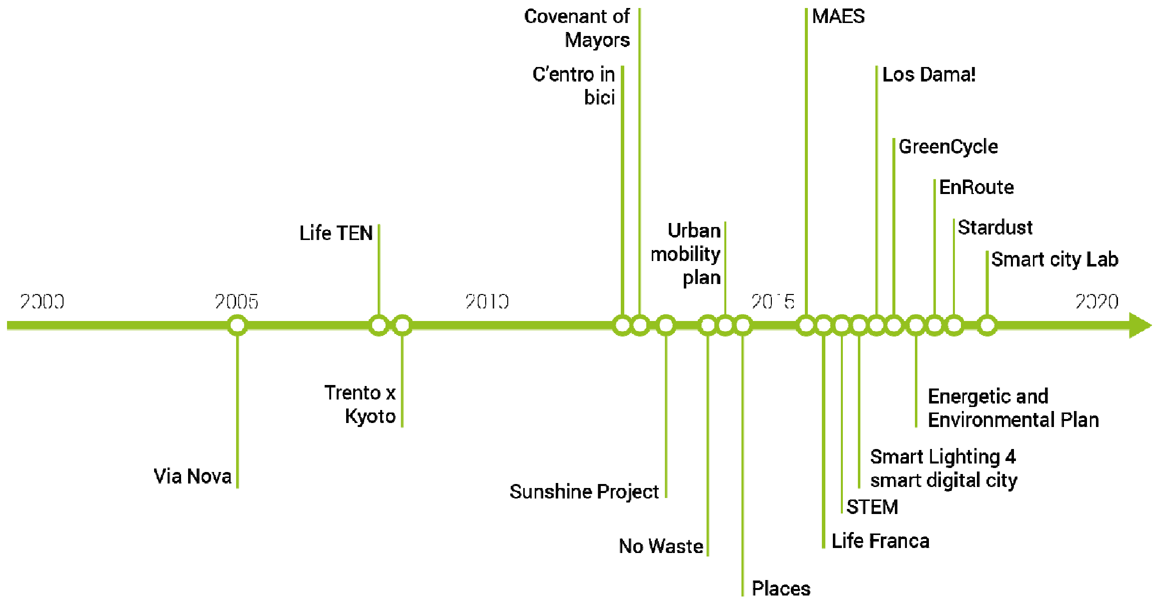
Governance. Trento aims to go beyond the top-down decision making, based on prescriptions, on the other hand it tends to open a dialog on decision-making, based on participation and representation.

Education. Education is considered one of the main objectives, in order to invest in human resources. Related to this objective is the development of education by the University of Trento and research activities carried out by other institutions (FBK, FEM, MUSE, etc)[73].

Critical elaboration of change. Contemporary cities live the contradictions brought about by technological, scientific and social progress. The intention of the urban planning of Trento is to avoid contradictions and promote a development that creates value in long term.

[73] See the Sistema Trentino Alta Formazione e Ricerca https://ricercapubblica.provincia.tn.it/Attori-della-ricerca-pubblica

5.5 Timeline


2000
2005
2010
2015
2020
Via Nova
Life TEN
Trento x Kyoto
Covenant of Mayors
C'entro in bici
Sunshine Project
Urban mobility plan
No Waste
Places
MAES
Life Franca
STEM
Smart Lighting 4 smart digital city
Los Dama!
GreenCycle
Energetic and Environmental Plan
EnRoute
Stardust
Smart city Lab

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