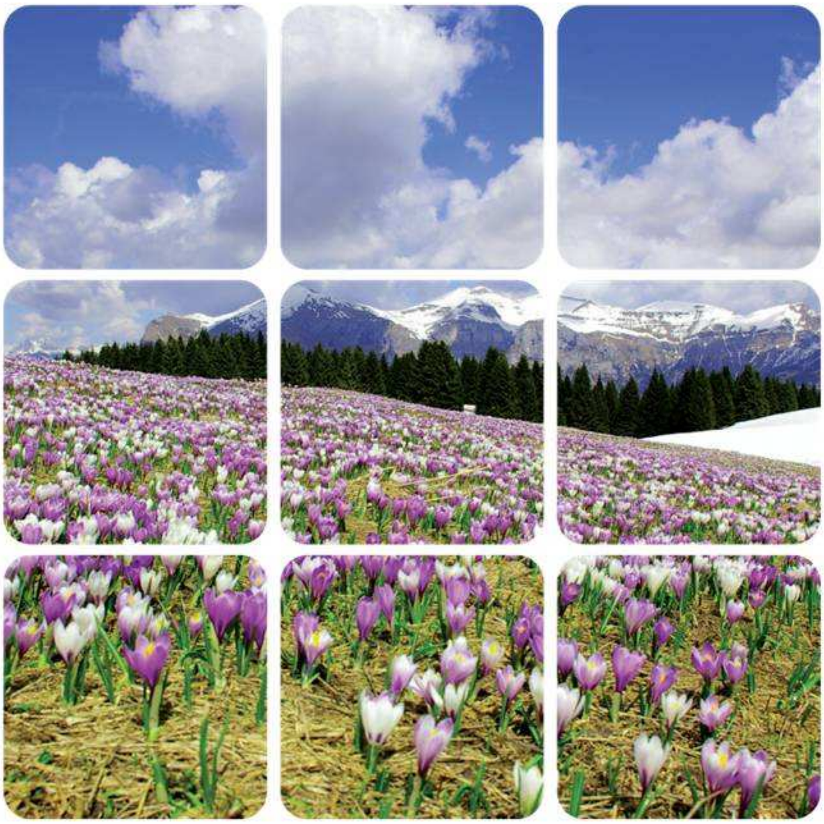
C3-ALPS

capitalising climate change knowledge for adaptation in the alpine space



Pilot activities in Brenta River basin (Italy)

University of Padua, Department Tesaf, Veneto Region,

Cà Foscari University of Venice, Department of Economics

funding programme

Alpine Space

EUROPEAN TERRITORIAL COOPERATION

THIS PROJECT IS CO-FUNDED BY THE EUROPEAN REGIONAL DEVELOPMENT FUND

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Delivery date	**18/09/2014**	
Status	**Final report**	
Distribution level	**Public**	**www.c3alps.eu**
ISBN	**978-88-908313-5-5**	

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1 Introduction

The C3 Alps research project seeks to synthesize, transfer, and implement in policy and practice the best available knowledge on adaptation, building on the results from previous projects and initiatives on adaptation to climate change in the Alps. By applying a knowledge-transfer concept, driven by the information and communication needs of project target groups, the project optimizes the usability of available knowledge resources in an attempt to bridge the gap between the generation of adaptation knowledge and its application in real-world decision-making.

This report consists of two main sections: the first one deals with the development of a local Early Warning System again water scarcity through the application and validation of the Water Scarcity Index (WSI), while the second one concerns the development of an online platform for supporting the analysis of Water Adaptation Measures. The first section, that corresponds to chapter n° 2, was realized by the Department Tesaf (University of Padua), in collaboration with Arpav, while the second section, that coincides with chapter n° 3 is due to the Venice Centre for Climate Studies (Ca' Foscari University of Venice). Both the WSI and the online platform for the analysis of Water Adaption Measures have been applied to the Brenta River basin.

2 Application and validation of Water Scarcity Index (WSI) to the Brenta River Basin

The Water Scarcity Index (WSI) was developed by ARPAV-DRST (Regional Agency for Environmental Protection and Prevention of the Veneto – Regional Department for the Security of Territory) within the European project “Alp Water Scarce”, with the purpose of setting up local Early Warning Systems again water scarcity. In January 2012, the WSI was first experimentally applied to the Piave river basin. Given the role of WSI, it should be applied both according to its trend and according to the measures adopted by the authorities in charge: the lower is the index, the greater is the deviation from the average values and, consequently, the worse is the likely situation. WSI may also play the role of monitoring system if the authorities in charge consider appropriate to adopt preventive measures following a warning. At first, the warning has to be issued throughout the authorities that deal with the management of water resources and then, throughout the end users. The most crucial months for the water resources supply are March, April, May and June. Nevertheless, a warning may also be issued in other periods, as much as it occurred in January 2012 for the Piave river basin. This project aims, at first, to improve and apply the WSI to the Brenta river basin, and then it attempts to validate the results obtained. The computation of WSI, as much as it was done for the Piave river basin, is based on a statistical analysis of the following hydro-meteorological variables: i) precipitation, ii) discharge, iii) temperature and iv) snow cover. We considered appropriate to apply the same methodology to the Brenta river basin as well, but with some innovative aspects related to the process of pluviometric, thermometric and nivological data. Although we will discuss better the methodology in Cap. 4, we consider appropriate to report below a brief description of how the index has been computed and how it works. At first, we collected daily data of the above-mentioned hydro-meteorological variables starting from 1 October 1990. Then, we carried out a statistical analysis based on percentiles. Once assigned to each variable a weight, we computed the WSI through a weighted average of the percentiles. The update of WSI depends on the update of the percentiles. Therefore, the WSI must be periodically computed. The WSI is a dimensionless number ranging from 0, for the most critical situation, to 1, for the best possible situation Relying on a solid database, a WSI threshold has been set, upon which it is possible to issue a warning. The threshold value has been defined equal to 0.5 for both Piave and Brenta river basins. We considered appropriate to evaluate the reliability of the index by assessing whether or not a correspondence between the predicted and the real scarcity exists for each hydrological year. If on one hand, it is quite simple to predict the water scarcity because it is sufficient that the index results to be lower than the threshold (0.5), on the other hand it is extremely demanding to prove a real situation of water scarcity, which is related to a certain area and a precise hydrological year. It is also true that a cause-effect relation is not always truthful: some months might have been particularly critical, but, at the same time, they might have not caused any damage. This may have been due to either natural and anthropic factors such as later abundant rainy periods or the intervention of the authorities in charge. To validate the results obtained, at first, we carried out a deep bibliographic research that affected all the information related to the real water scarcity periods occurred. At this regard, we would like to stress the difficulty to find reliable written material dated back before 2000. This fact, combined with the low quality of hydro-meteorological data of the period from 1990 to 2000, made the validation process start from the hydrological year 2000-2001. The validation processes also included the computation of monthly WSI for each hydrological year starting from 2000-2001.

2.1 Study area

The study area coincides with the mountainous portion of the Brenta river basin closed at the discharge measuring station of Barziza, located within the municipality of Bassano del Grappa (province of Vicenza). The whole study area is about 1567 km^2, whose about 30% is located in the Veneto Region and the remaining 70% in the Autonomous Province of Trento (Fig. 1).

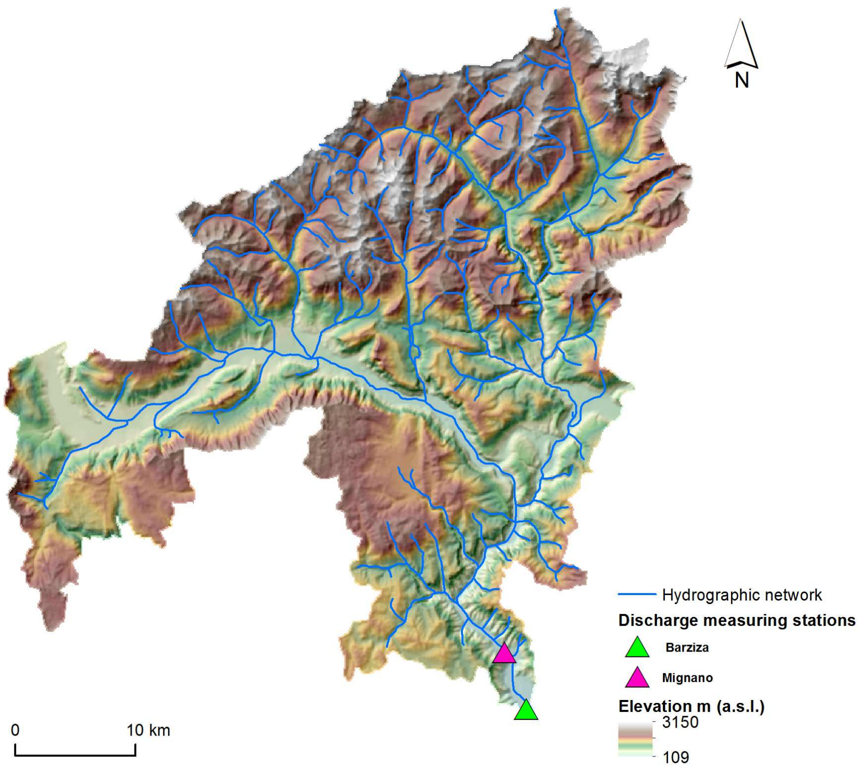

Figure 1: Brenta river basin closed at the discharge measuring station of Barziza. The figure shows the Digital Terrain Model (DTM) and the hydrographic network of the basin. The former was obtained by merging single portions of DEM that were downloaded from the websites of the administrative authorities. The latter was taken from a freely and available on-line national database. The figure also reports the discharge measuring station of Mignano, located about 8 km northern than Barziza.

Figure 2 shows the hypsographic curve and the mean elevation (1247 m a.s.l.) of the basin that were derived from a 10 m DTM. The basin ranges from a minimum elevation of about 109 m a.s.l. to a maximum value of about 3150 m a.s.l. The basin is characterized by an average slope of about 22 ° with a maximum value equal to about 72°.

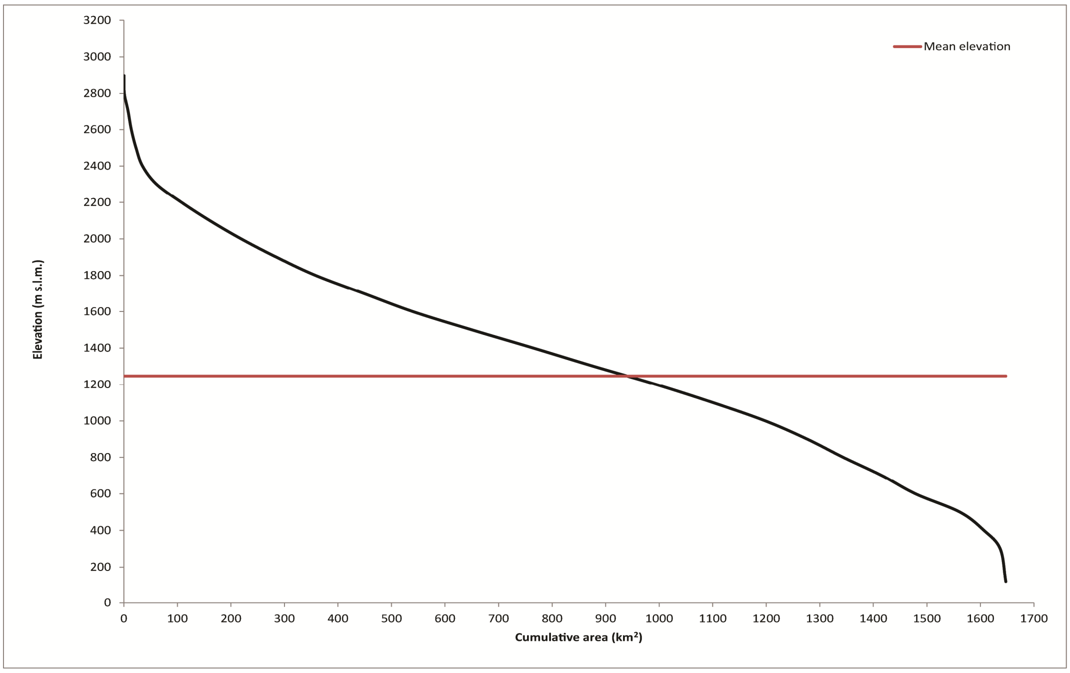

Figure 2: Hypsographic curve for the Brenta river basin

The land use cover of the study area is mainly made of forest and semi-natural areas (88.4%), followed by agricultural areas (9.6%), artificial surfaces (1.6%) and water bodies (0.4%) (Fig. 3).

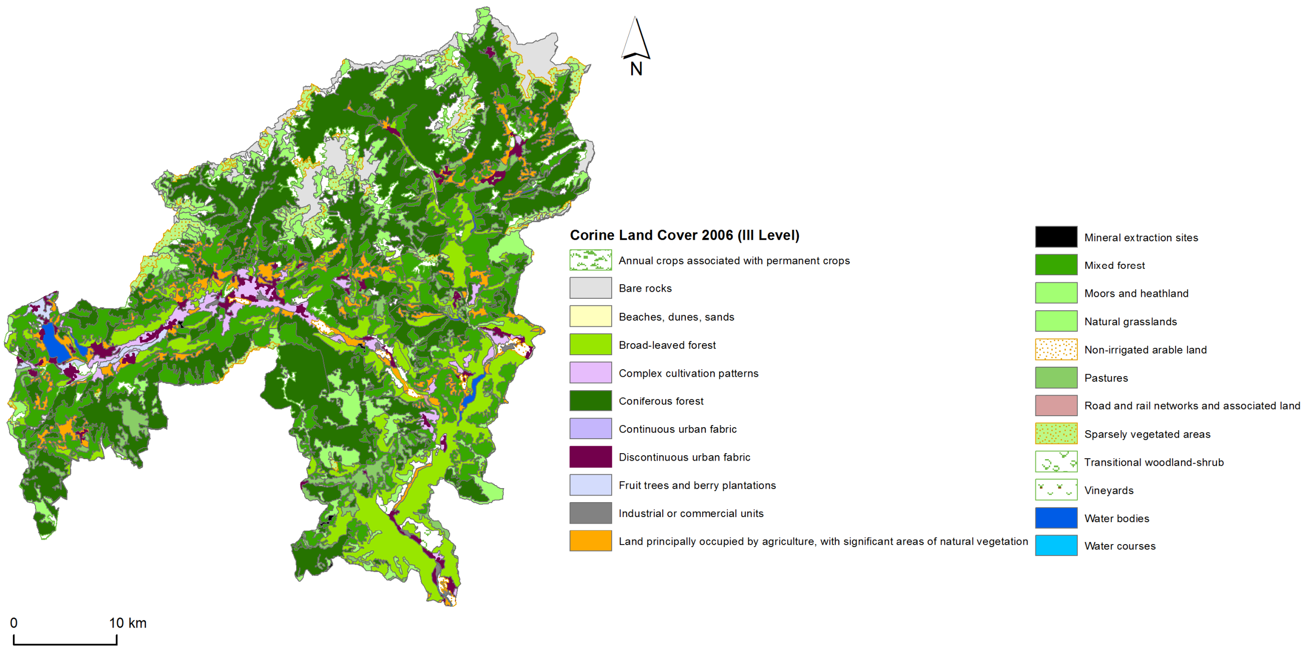

Figure 3: Corine Land Cover map of the Brenta river basin dated back 2006. By looking at the map, emerges the prevalence of greenish colors that stand for the category of forest and semi-natural areas.

2.2 Hydro-meteorological network

The presence on the territory of a reliable weather station network is essential for obtaining a result that is scientifically accepted. At this regard, a great effort was put into delineating the official weather station network. This was also due to the fact that the basin falls within two different administrative regions. For the computation of the WSI, the following hydro-meteorological variables were taken into consideration: i) precipitation, ii) discharge, iii) temperature and iv) snow cover height. Of these variables, daily data were collected starting from 1 October 1990. To have a weather station network that was as most widespread as possible, it has been necessary to rely on databases managed by different authorities:

- *Meteotrentino*, *Fondazione Edmund Mach*, *Ufficio Dighe Autonomous Province of Trento (PAT)* and *Sirav* (ARPAV) for precipitation and temperature data
- *Sirav* and *ENEL* for for discharge and snow cover height data

All the authorities reported above belong to either regional or provincial agencies, except for *ENEL* that is a private company dealing with energy production.

For each of the above-mentioned variable, the official weather station networks are reported below.

2.2.1 Precipitation

Figure 4 shows the distribution over the basin of the twenty-five rain gauges considered. Figure 5 reports the distribution of the rain gauges according to the elevation classes of the basin.

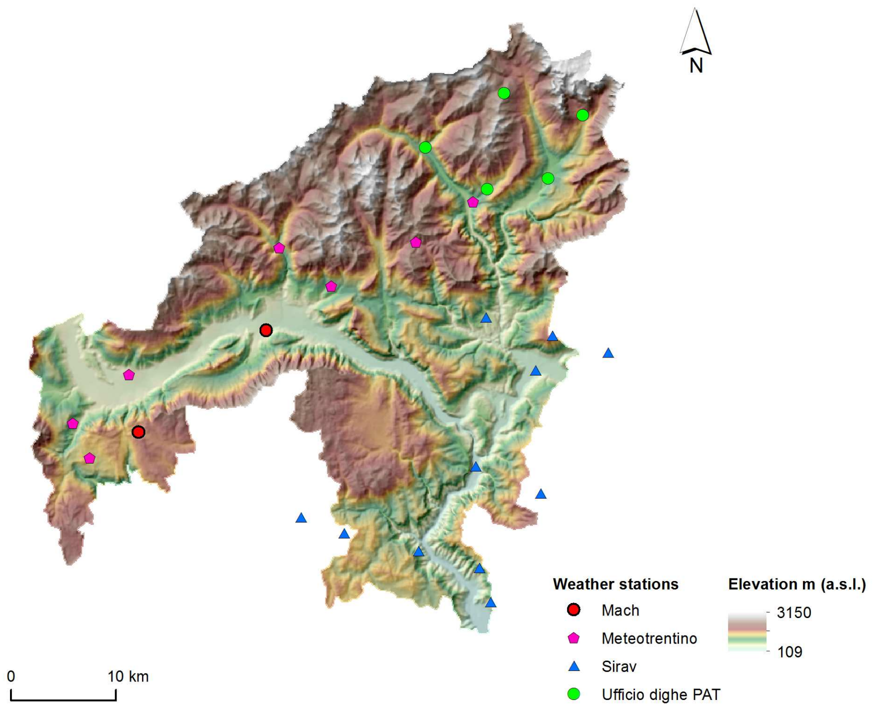

Figure 4: The twenty-five rain gauges considered for the WSI computation

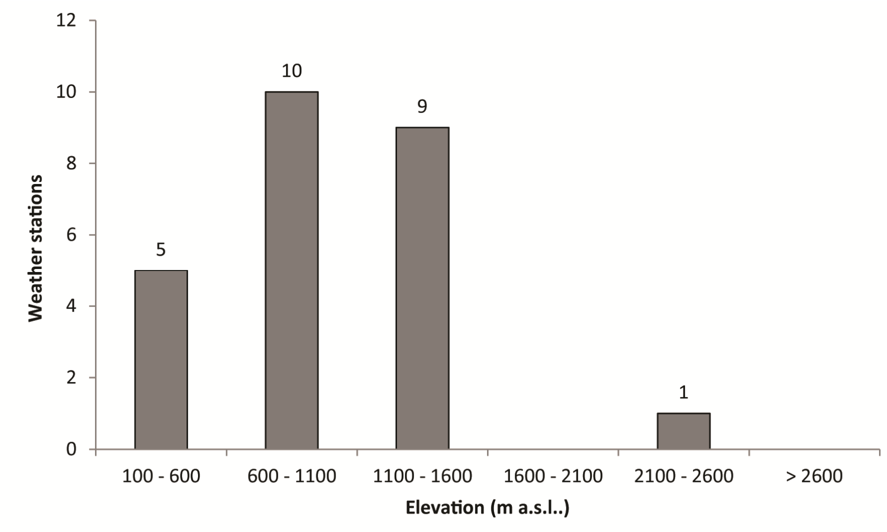

Figure 5: Plot showing the distribution of the rain gauges according to the elevation classes of the basin

2.2.2 Temperature

Figure 6 shows the distribution over the basin of the seventeen thermometric stations considered. Figure 7 reports the distribution of the thermometric stations according to the elevation classes of the basin.

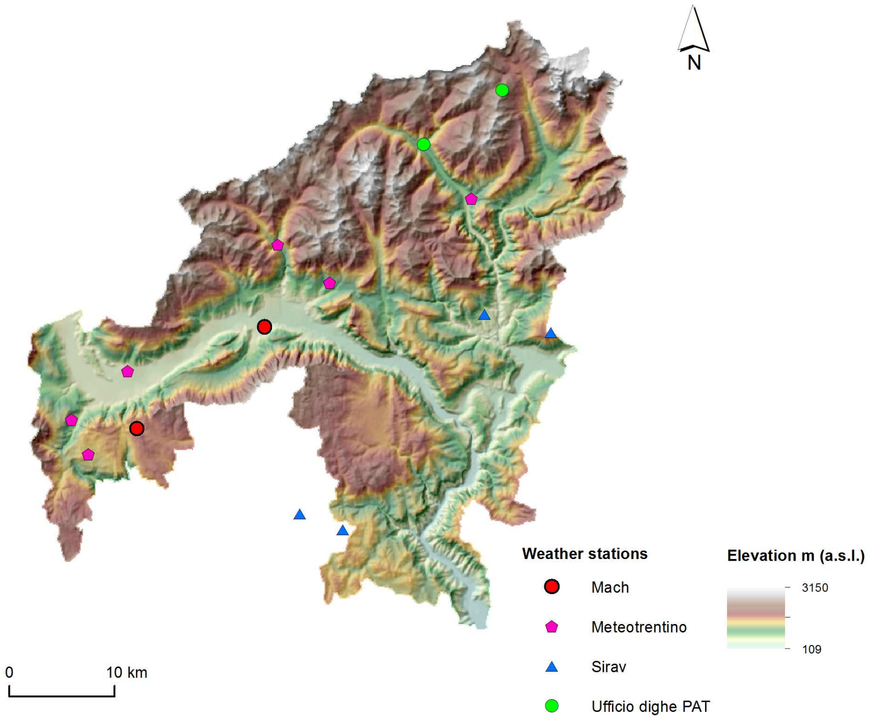

Figure 6: The seventeen thermometric stations considered for the WSI computation

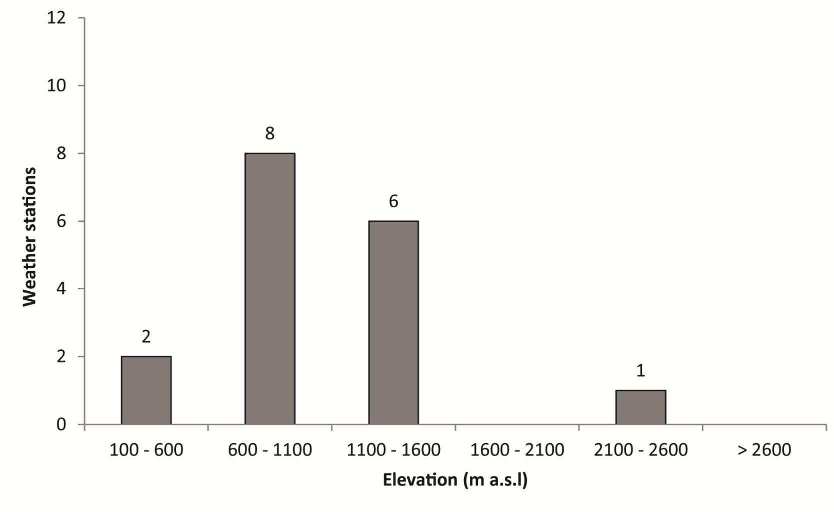

Figure 7: Plot showing the distribution of the thermometric stations according to the elevation classes of the basin

2.2.3 Snow cover height

Figure 8 shows the distribution over the basin of the nine snow monitoring stations considered. Figure 9 reports the distribution of the snow monitoring stations according to the elevation classes of the basin.

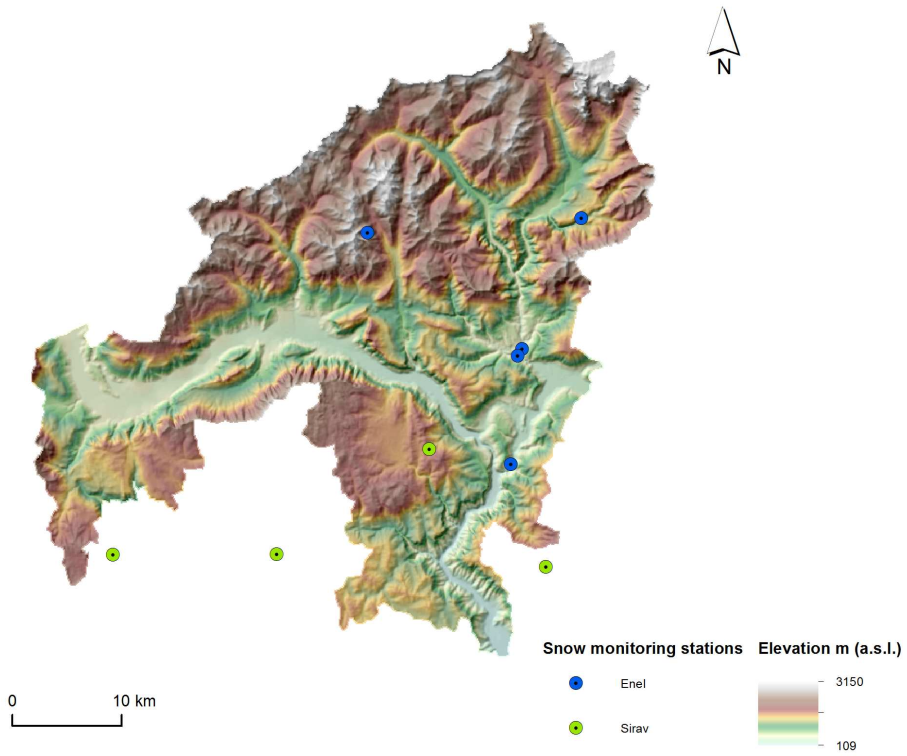

Figure 8: The nine snow monitoring stations considered for the WSI computation

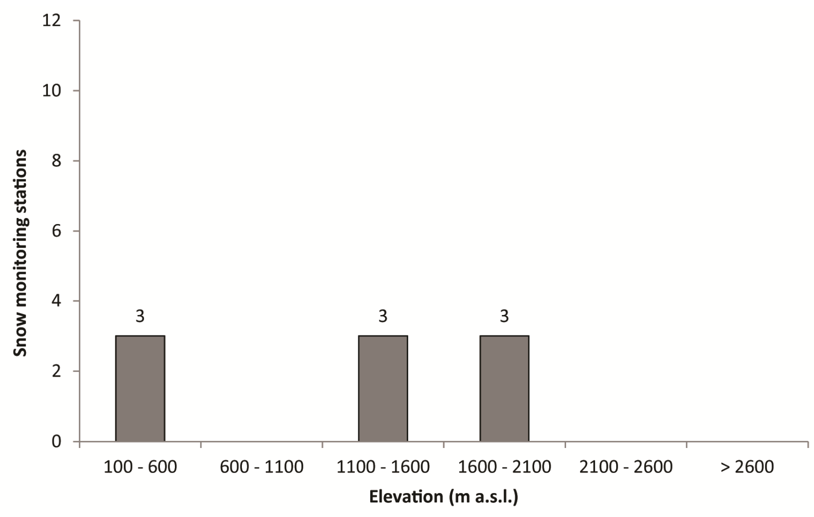

Figure 9: Plot showing the distribution of the snow monitoring stations according to the elevation classes of the basin

At this regard, a remark must be done. ENEL provided data until 31 August 2013. From that data on, only data given by ARPAV (Sirav) have been used. For this reason, to evaluate the representativeness of ARPAV stations for the whole basin, the Pearson correlation has been computed for each station (Tab. 1). The good results obtained allowed us to keep collecting only snow cover data derived from ARPAV stations.

Table 1: Pearson coefficients computed for each ARPAV snow monitoring stations.

	Pearson coefficient
Campomolon	0.91
Malga Larici	0.95
Monte Lisser	0.90
Monte Grappa	0.86

2.3 Discharge

Figure 10 shows the location of the two discharge measuring stations considered: Barziza and Mignano. The former one is the main one, managed by ARPAV, upon which it was considered appropriate to close the basin. Nevertheless, Barziza measuring station did not work at all for eight years, from 1997 to 2003 and, for this reason, we had to fill the gap by collecting data coming from Mignano measuring station, located about 8 km northern than Barziza. The fact that Mignano measuring station is managed by ENEL, a private company for energy production, made the collection of data more difficult.

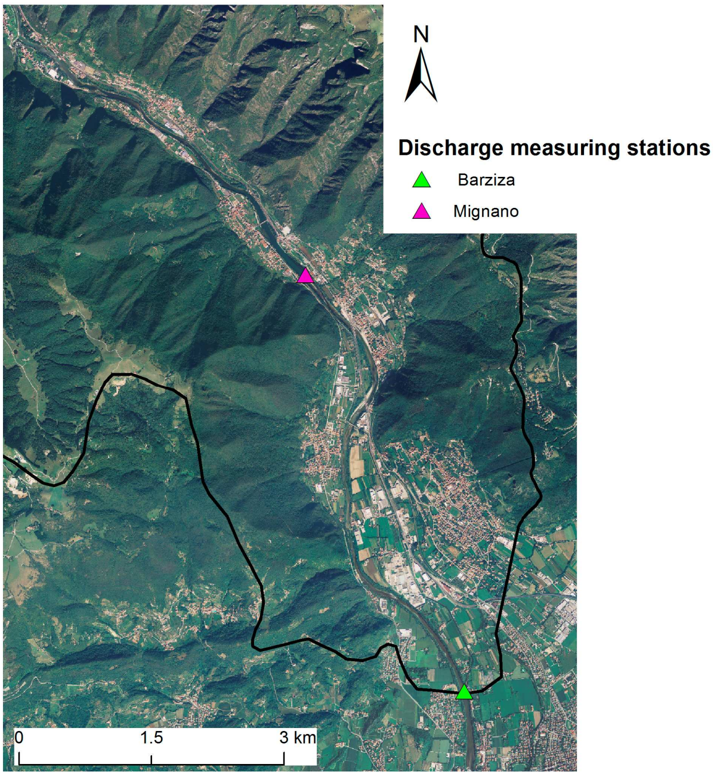

Figure 10: Location of Barziza and Mignano discharge measuring stations

2.4 Computation of Water Scarcity Index

The computation of WSI, as much as it was done for the Piave river basin, is based on a statistical analysis of the following hydro-meteorological variables: i) precipitation, ii) discharge, iii) temperature and iv) snow cover. We considered appropriate to apply the same methodology to the Brenta river basin as well, but with some innovative aspects related to the process of pluviometric, thermometric and nivological data. For all the variables, daily data were collected starting from 1 October 1990.

Regarding pluviometric data, once we removed not reliable values, we distinguished rainfall from snowfall based on the mean daily temperature values. We defined a temperature threshold equal to 0.5 °C upon which to distinguish the liquid-phase from the solid-phase of precipitation. Afterwards, we applied a snow correction factor equal to 1.6 ° C to those precipitation values occurred as solid-phase (Carturan et al., 2012). This was done to fix possible underestimation errors that usually affect snowfall. Then, we also improved precipitation values by applying an elevation correction factor assuming a mean increase of 2 mm in precipitation every 100 m of increase in elevation. Once we filled the time series data gaps, we interpolated data to end up with a daily mean areal precipitation. We considered appropriate to apply the Inverse Distance Weighting (IDW) method.

In terms of thermometric data, once we removed not reliable values, we partitioned the basin in four sub-catchments based on the topography and, for each sub-catchment, we selected the most reliable thermometric stations (Fig. 11).

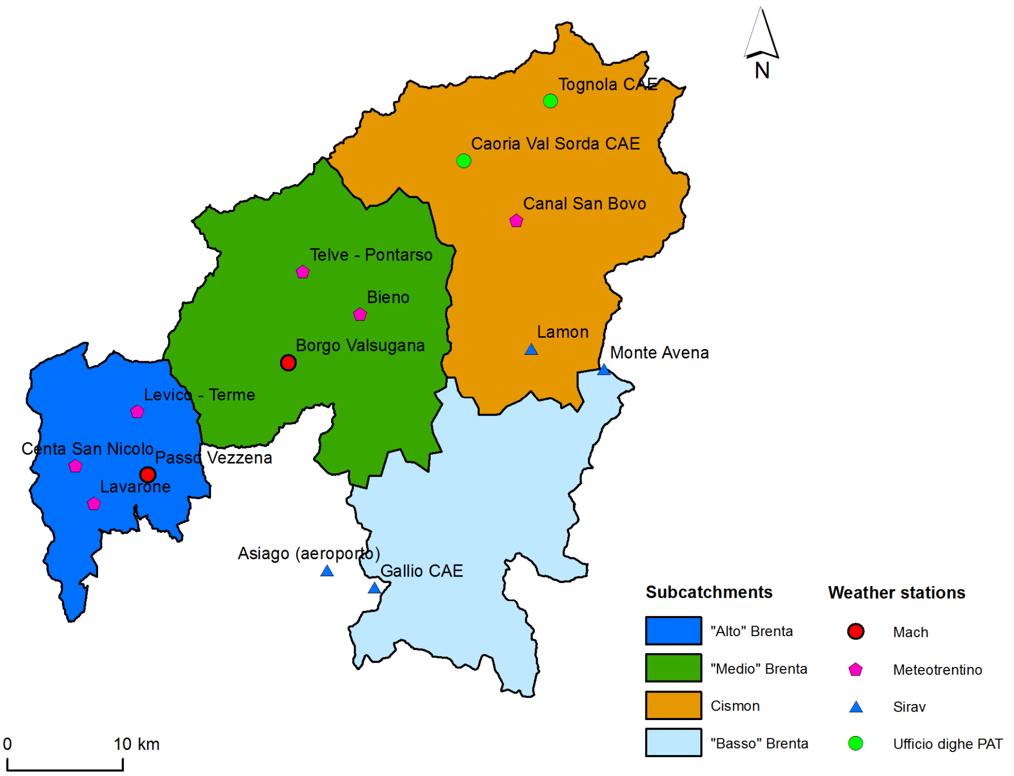

Figure 11: Partitioning of the Brenta river basin in four sub-basins: “Alto” Brenta, “Medio” Brenta, “Cismon”, “Basso” Brenta.

The partitioning in sub-catchments and the definition of a reference thermometric station for each sub-catchment allowed to compute a mean temperature gradient for each sub-catchment (Tab. 2).

Table 2: Extension, mean elevation, reference thermometric station and mean temperature gradient computed for each sub-basin.

	Alto Brenta	Medio Brenta	Cismon	Basso Brenta
Extension (km^2)	225	479	576	370
Mean elevation (m)	1049	1343	1460	913
Reference themometric station	Lavarone	Telve Pontarso	Canal San Bovo	Asiago
Mean temperature gradient (°C/m)	0.0062	0.0070	0.0055	-0.0027

Through the mean temperature gradient, daily temperature values were then related to the mean elevation of the whole basin. In the end, as much as it was done for precipitation, data were interpolated through the IDW to end up with a daily mean areal temperature.

Regarding snow cover data, once we removed not reliable values, we partitioned the whole basin in four elevation classes according to the hypsographic curve of the basin (Fig. 12).

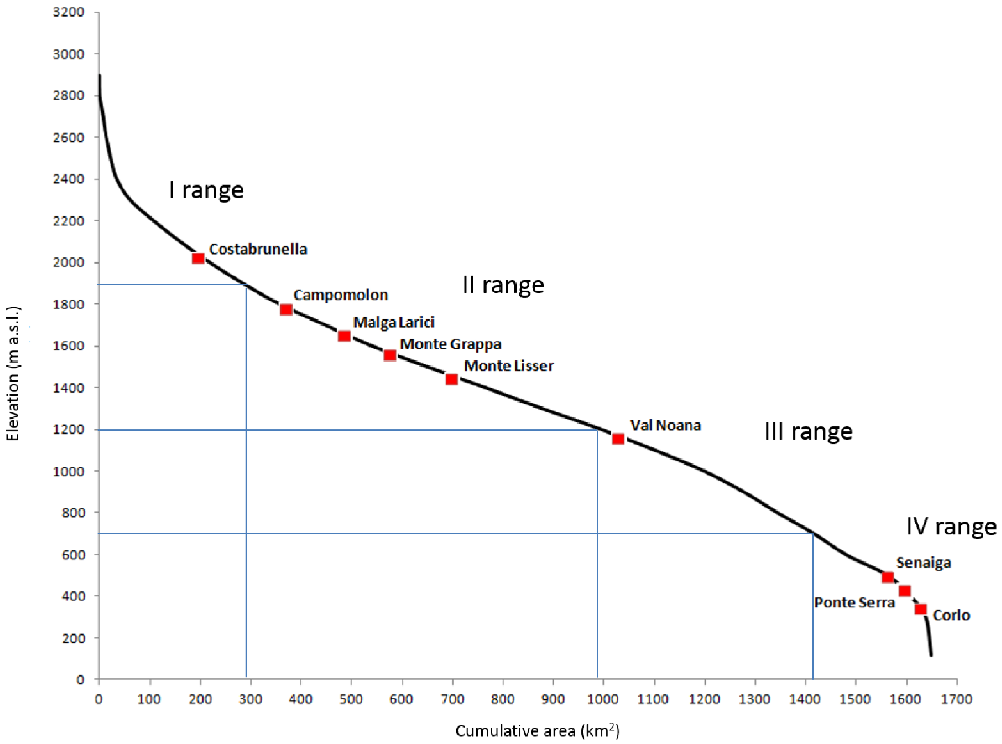

Figure 12: Hypsographic curve of the Brenta river basin alongside the nine snow monitoring stations are located

Afterwards, to each elevation class, we assigned a weight based on the ratio between the area covered by the range itself and the whole basin area (Tab. 3). In the end, a weighted average was computed to end up with a daily snow cover value that was effective for the whole basin.

Table 3: Snow monitoring stations and weighting factor identified for each elevation class

	Area (km^2)	Weighting factor	Snow monitoring stations
I range	285	0.17	Costabrunella
II range	709.5	0.43	Campomolon, Malga Larici, Monte Grappa, Monte Lisser
III range	421.5	0.26	Val Noana
IV range	231.5	0.14	Senaiga, Ponte Serra, Corlo

In the end, regarding discharge data, a particular process of data validation has not been carried out. The fact that must be highlighted is that we had to fill up a consistent data gap from 1997 to 2003 due to the

out of service of Barziza measuring station. For this reason, we had to collect data provided by Mignano measuring station. Other than this, the daily series data were ready to be subjected to the statistical analysis.

Once we had reliable and continuous daily series data for each hydro-meteorological variable, we proceeded with the statistical analysis based on percentiles. For each hydro-meteorological variable, some parameters were considered upon which percentiles were then computed. To each parameter, we assigned a weight, as much as it was done for the Piave river basin (Tab. 4).

Table 4: Parameters considered for each hydro-meteorological variable and the corresponding weight given.

	Weight	Variable	Code
Cumulative rainfall from 1st October	0.05	Precipitation	P1
Cumulative rainfall from 1st December	0.15	Precipitation	P2
Men temperature from 1st October	0.05	Temperature	T1
Mean temperature from 1st March	0.10	Temperature	T2
Mean snow cover height (10 days) from 1st October	0.15	Snow cover	SW1
Cumulative of fresh snow from 1st October	0.10	Snow cover	SW2
Minimum mean discharges (10 days) from 1st October	0.20	Discharge	Q1
Minimum discharges (10 days) from 1st October	0.10	Discharge	Q2
Cumulative outflow volumes from 1st January	0.10	Discharge	Q3

The WSI is then computed as follows:

$$WSI = \sum P * 0.20 + \sum T * 0.15 + \sum SW * 0.25 + \sum Q * 0.40 \quad (1)$$

The WSI is a dimensionless number ranging from 0 to 1: the lower is the index and the worse is the situation. A threshold has been set equal to 0.5, upon which it is possible to issue a warning, as much as it was done for the Piave river basin. The update of WSI depends on the update of the percentiles. Therefore, the WSI must be periodically computed.

2.5 Results and validation

Among the results, we report the WSI computed every 15 days starting from January 2014 (Tab. 5). The results obtained show WSI values much greater than the standard threshold (0.5). These results proves that the current year has been very abundant in terms of water resources supply.

Table 5: WSI computed every fifteen days from January 2014 until 31th of August.

	15th January	15th February	15th March	15th April	15th May	15th June	15th July	15th August
WSI	0.79	0.88	0.81	0.80	0.78	0.76	0.78	0.85
	31th January	28th February	31th March	30th April	31th May	30th June	31th July	31th August
WSI	0.85	0.90	0.81	0.80	0.78	0.76	0.80	0.81

As already stated in Cap. 1, validation process consisted in both a deep bibliographic research aimed at finding a correspondence between a predicted and a real water scarcity situation and the computation of monthly WSI for each hydrological year starting from 2000-2001 (Tab. 6). A monthly trend of the WSI may be very helpful to better understand and predict a possible critical situation.

Table 6: Monthly WSI computed for each hydrological year starting from 2000-2001

	31th Jan	28th Febr	31th Mar	30th Apr	31th May	30th Jun	31th Jul	31th Aug	30th Sep
2000-2001	0.79	0.78	0.81	0.82	0.83	0.70	0.72	0.72	0.71
2001-2002	0.15	0.36	0.17	0.30	0.59	0.53	0.61	0.66	0.65
2002-2003	0.73	0.66	0.49	0.42	0.40	0.42	0.46	0.36	0.30
2003-2004	0.60	0.74	0.78	0.81	0.92	0.87	0.85	0.86	0.71
2004-2005	0.61	0.57	0.51	0.46	0.45	0.37	0.43	0.44	0.44

2005-2006	0.68	0.76	0.77	0.75	0.71	0.57	0.56	0.62	0.56
2006-2007	0.35	0.38	0.41	0.24	0.32	0.44	0.44	0.39	0.37
2007-2008	0.50	0.50	0.50	0.53	0.64	0.76	0.79	0.78	0.78
2008-2009	0.94	0.94	0.89	0.86	0.83	0.78	0.79	0.80	0.77
2009-2010	0.74	0.80	0.78	0.68	0.81	0.81	0.74	0.80	0.78
2010-2011	0.83	0.85	0.83	0.64	0.63	0.73	0.72	0.73	0.67
2011-2012	0.27	0.29	0.08	0.19	0.23	0.23	0.27	0.23	0.23
Mean WSI	**0.60**	**0.64**	**0.59**	**0.56**	**0.61**	**0.60**	**0.61**	**0.62**	**0.58**

From Tab. 6, what emerges is that the hydrological years of 2006-2007 and 2011-2012 result to be the most critical ones of the last thirteen years. This was proved by the materials found in literature, such as the bulletins produced by ARPAV. In years such as 2001-2002 and 2002-2003, WSI showed a different trend: in the latter one WSI progressively decreased as spring was approaching, while in the former one WSI showed an opposite behavior. This may be due to both natural or anthropic reasons such as a later abundant rainy spring or the intervention of the authorities in charge.

Figure 13 shows the WSI computed every month from January 2014 in relation to the standard threshold (0.5) and the mean WSI trend. This proves that WSI values computed for the current year are, by far, above both the standard threshold and the mean values derived from the historical analysis.

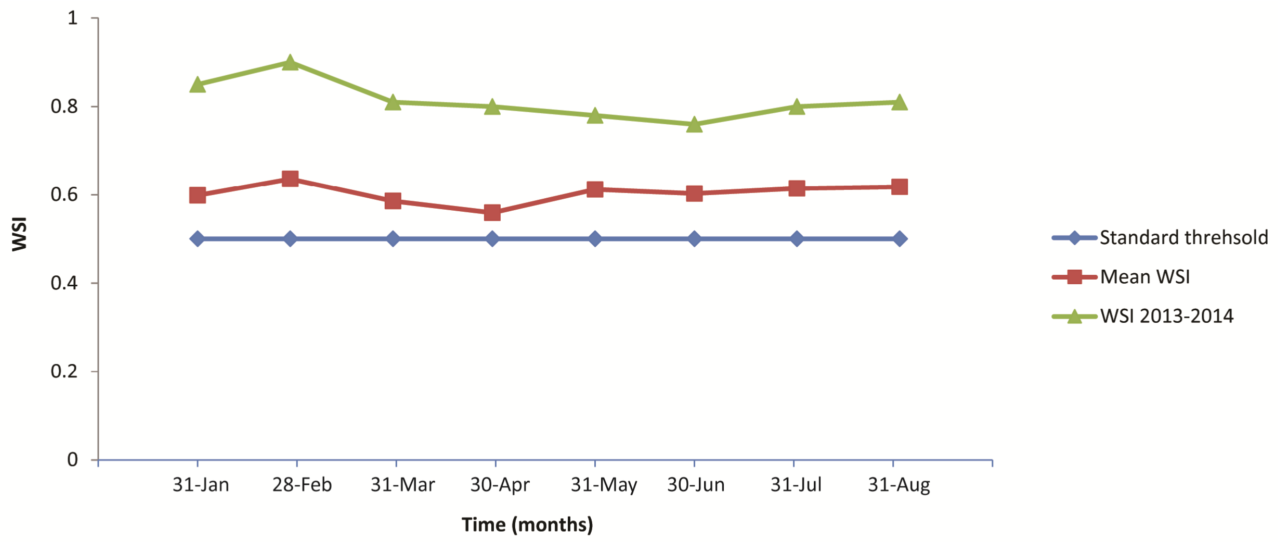

Figure 13: Plot showing the WSI computed every month starting from January 2014 in relation to the standard threshold (0.5) and the mean WSI.

In conclusion, relying on historical mean monthly values of WSI may be very helpful to better predict likely critical situations. WSI that are above the standard threshold but at the same time, below the mean historical values deserve particular attention because they may be a sign of forthcoming water scarcity. Therefore, we suggest relying on the mean monthly values of WSI other than the standard threshold to issue a possible warning.

3 An Online Platform for Supporting the Analysis of Water Adaptation Measures in the Brenta River basin

The C3 Alps project involves stakeholders in different ways, among others through eParticipation in the form of online surveying and collaboration on problem analysis and solution finding, in order to support bottom-up development of adaptation measures in the Alpine regions and municipalities.

At the following step, eParticipation empowered stakeholders to collaborate on the analysis of alternative adaptation measures and suitable solutions using a platform that combines a spatial tool – Map Viewer – and a multi-criteria decision-support component – mDSSweb. The C3 Alps Map Viewer is an interactive web mapping application based on open source WebGIS technologies and using Google Maps as base map (Fig. 14). While the Map Viewer provides the routines for geo-localization and the display of results, mDSSweb guides users through the elicitation and sharing of their preferences and expectations regarding a set of climate change adaptation measures, identified by the project consortium as being of specific interest in the field of water resources management and climate change.

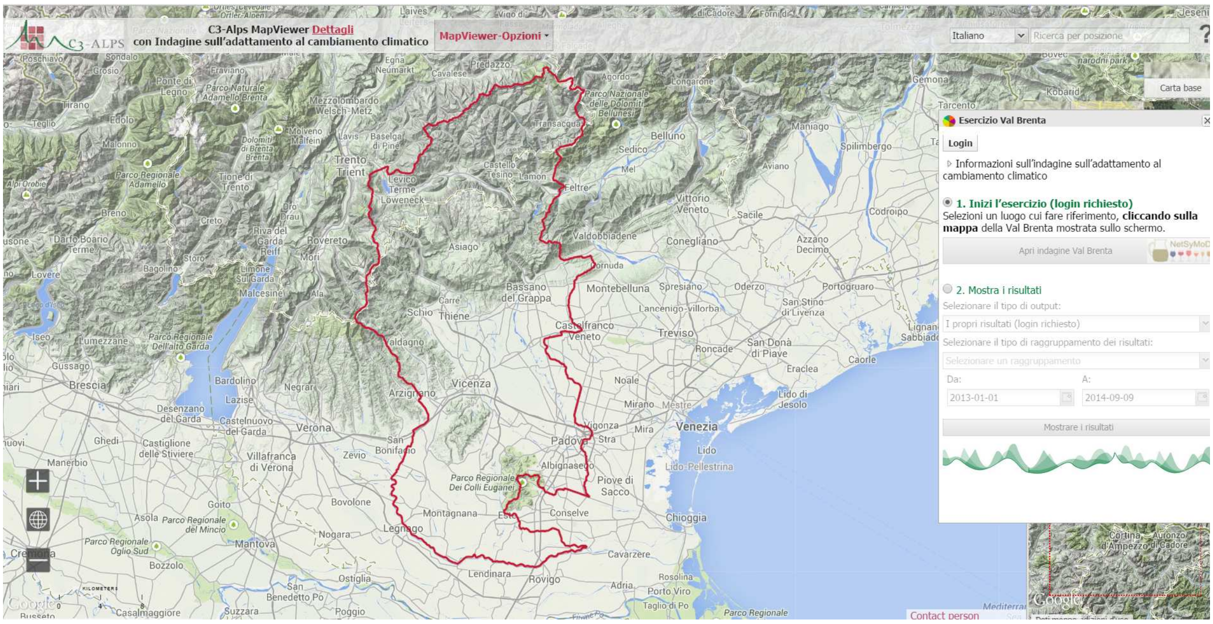

Figure 14: C3 Alps Map viewer

The qualitative evaluation of alternative measures is performed through an interface with which the user fills in the Analysis Matrix (AM). Specifically, the user attaches a value in each cell of the matrix to express their expectations as to the performance of each alternative measure for every evaluation criterion (Fig. 15). The proposed values range from 1 (very low performance) to 5 (very high performance). The matrix reported in Figure 15 is in Italian, since the case study was of local interest, but multi-lingual versions are available (English, German, Italian and Slovene) for the analogous case exercise proposed to the stakeholders of the whole Alpine Space.

MATRICE DI ANALISI																										
		Misure																								
		A. Infrastrutture idriche					B. Conservazione dell'acqua					C. Riuso di acque reflue					D. Campagne di sensibilizzazione					E. Strumenti di pianificazione				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Criteri	Efficacia	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Efficienza	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Prestazioni ambientali	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Effetti collaterali	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Risoluzione di conflitti	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Incertezza dei risultati	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Figure 15: Analysis matrix for the evaluation of alternative measures.

After the compilation of the AM, the user weights criteria according to their relative importance. The weights are decided upon through a graphical interface with a revised Simos technique that allows any user/stakeholder, even if they are not familiar with multi-criteria decision analysis, to think about and express the relative importance of criteria in the given context (Figueira and Roy, 2002).

Using MCA evaluation techniques, alternative options are evaluated against their criteria performances by applying aggregation algorithms[1] to the set of values stored in the AM and in the criteria weight vector.

This particular exercise analyses alternative measures that can help the Brenta watershed adapt to water scarcity resulting from climate change.

The following set of climate change adaptation measures was identified by the C3-Alps project consortium:

A. Improving water infrastructures and reducing leakage, thus saving water by controlling and limiting water leakage from inefficient and/or ageing municipal and agricultural water distribution systems. This is an engineering-based measure.

B. Improving water efficiency and conservation in households and hotels, thus reducing water wastage by decreasing the water consumption of households and hotels. This measure involves choosing more water-efficient devices, products, and practices. It may be supported by specific codes, protocols, and certifications, and in extreme cases (drought periods) it may include restrictions and rationing that may temporarily limit certain uses of water, for example the irrigation of lawns and car washing. This is a set of voluntary and behavioural measures.

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1 Simple Additive Weighting – the final score of each adaptation option is calculated with the sum of the criterion values, weighted by the vector of weights (Giupponi et al., 2006).

C. Introducing wastewater treatment and reuse, involving the reuse of domestic water from baths, showers and sinks (grey water) for toilet flushing, laundry/dish washing and gardens. The grey water from households and hotels could also be reused in industry and agriculture, e.g., for irrigation, greenhouses, and industrial processes. This measure reduces overall demand for water, thereby easing pressure on available water. This is a combination of technological and management measures.

D. Undertaking awareness-raising campaigns and promoting behavioural changes (focusing on tourists), involving campaigns for promoting awareness of the impacts of climate change on water availability and the active role that tourists can play in reducing the negative consequences of water use. Public awareness is important to increase enthusiasm and support, stimulate self-mobilization and action, and to mobilize local knowledge and resources. Tourists are informed about simple water-saving actions they can take in their daily routines. This behavioural measure can be combined with other technology or management options.

E. Improving planning instruments for water saving, thus protecting water resources through planning instruments that reduce the water requirements of targeted sectors and enable the optimal use of available water resources. These planning instruments include zoning, financial incentives and disincentives, regulatory measures, market-based instruments, strategic planning for catchment and resource management, including water use for artificial snow. This alternative includes a vast catalogue of measures to be implemented through planning instruments and legislation.

The alternative measures are evaluated against the following set of criteria defined on the basis of previous experiences in the field:

1. Effectiveness – the extent to which the adaptation measures directly contribute to reducing the system's vulnerability to the expected impacts of climate change.

2. Efficiency – the characteristic of measures that bring higher benefits in comparison to their costs of implementation, including transaction and monitoring costs.

3. Environmental performance – the potential contribution of a measure to improve or protect the state of the environment, for example by contributing to pollution abatement, the conservation of natural habitats, natural resources and ecosystem services.

4. Side-effects – the unintended outcomes, both positive and negative, of the adaptation measures, going beyond their specific scope: e.g., positive effects on employment, or negative side effects on different environmental aspects.

5. Contribution to the resolution of conflicts – the potential contribution of a measure to limit existing conflicts, for instance conflicts amongst different sectors competing for the same water resource.

6. Performance under uncertainty – the capability of the measures to maintain their performance under a wide range of uncertain future changes in climatic and socio-economic conditions. Measures that meet this requirement may be either robust to uncertainties or flexible in design and implementation.

After finishing the exercise, the users are redirected to the MapViewer where they can visually explore the results. Individual results are presented through the following graphs:

- Overall performance of adaptation measures and criteria contributions – the MCA results are reported by the platform in the form of a histogram in which the length of the bars are proportional to the scores and the colour segments show how the weighted performances of each criterion contribute to the overall performance of a measure (Fig. 16)
- Sustainability performance – the performances of the measures are balanced according to the three dimensions of sustainability: economic, environmental and social. These performances are presented in a triangular chart in which scores are calculated for each dimension by assigning the criteria values to one or more sustainability pillars. Ideally, options should be presented as equivalent triangles. Alternatively, they denote the fact that the three dimensions are not balanced (Fig. 16).

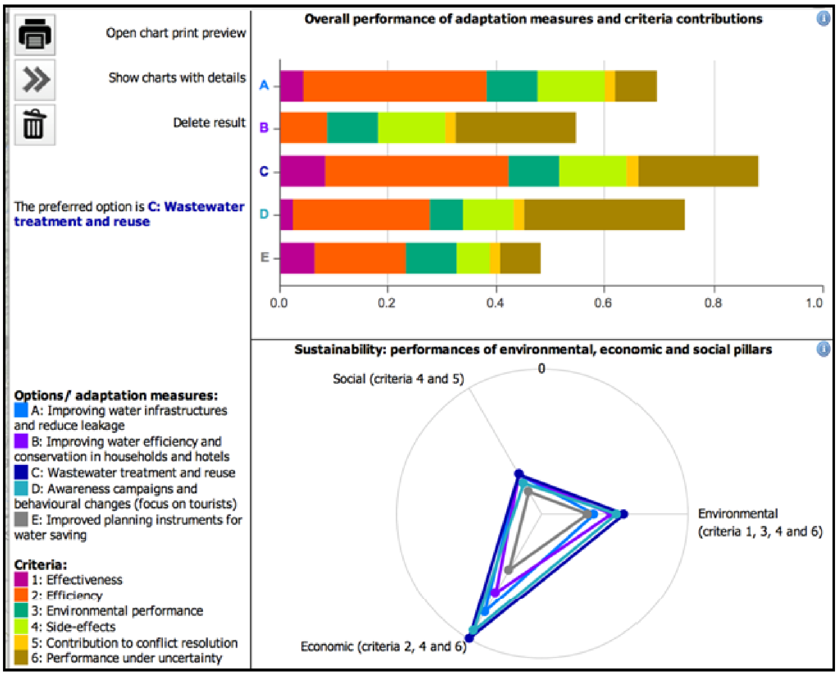

Figure 16: Overall performance of adaptation measures and criteria contribution (upper chart) and Sustainability performance (Lower chart) – the winning option C better fulfils economic, than social and environmental dimension.

- Evaluation of the options against the criteria – a polar graph shows how the adaptation options perform according to the criteria considered before weighting (Fig. 17). A regular polygon shows similar performances, while irregular shapes denote notable differences between the alternative options. Polygons with vertices closer to the centre of the chart denote poor performances while vertices close to the external rings show good performances.

- Relative importance of criteria – a pie-chart shows the relative importance (weight) assigned to each of the criteria (Fig. 17). These weights are used to calculate the final score, i.e., overall performance and sustainability performance.

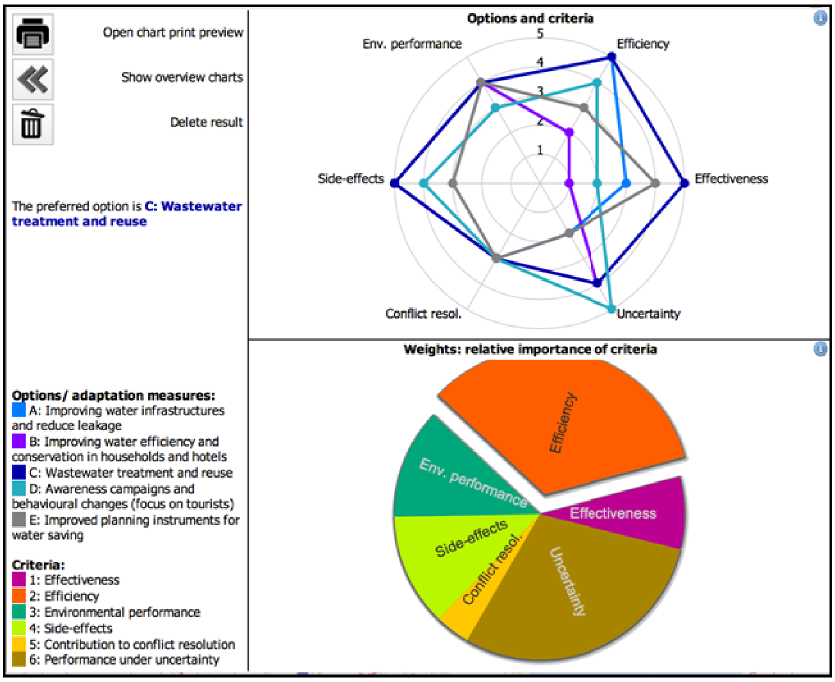

Figure 17: Evaluation of the options against the criteria before criteria weighting (upper chart) and Criteria weighting (lower chart) – efficiency is marked as the most important criterion.

Individual results are combined in a summary screen showing a synthesis of all the collected contributions.

3.1 The overall results of the exercise

This exercise was distributed among a narrow group of stakeholders interested in this particular case – 17 participants. A group of the students at the Ca' Foscari University of Venice – 10 participants – used the exercise as well. Analysing the results obtained from 27 participants, we see that a compromise overall solution shows the highest score for the first option A - Improving water infrastructures and reducing leakage and C - Waste water treatment and reuse (Fig. 18).

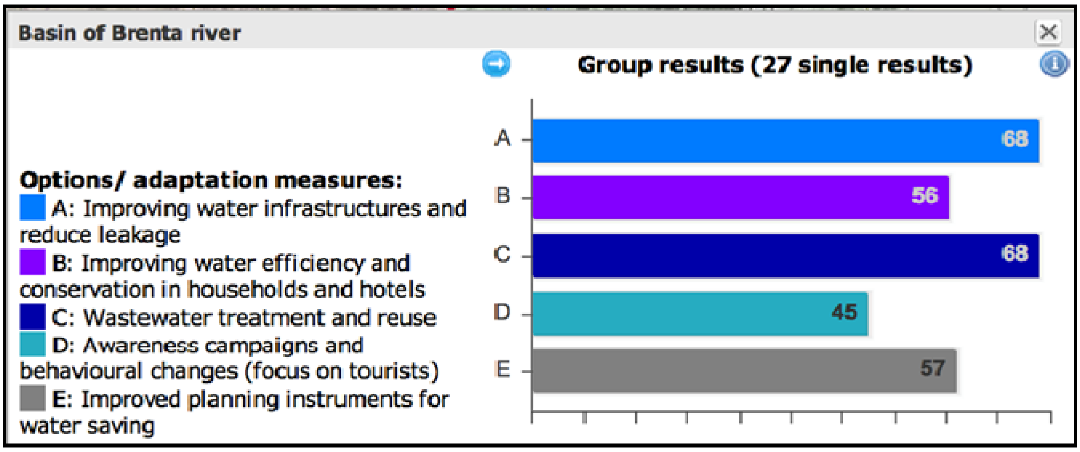

Figure 18: The overall result of the exercise

Looking into how the participants weighted the offered evaluation criteria, we can see that the most importance is given to effectiveness and efficiency, followed by the environmental performance (Fig. 19).

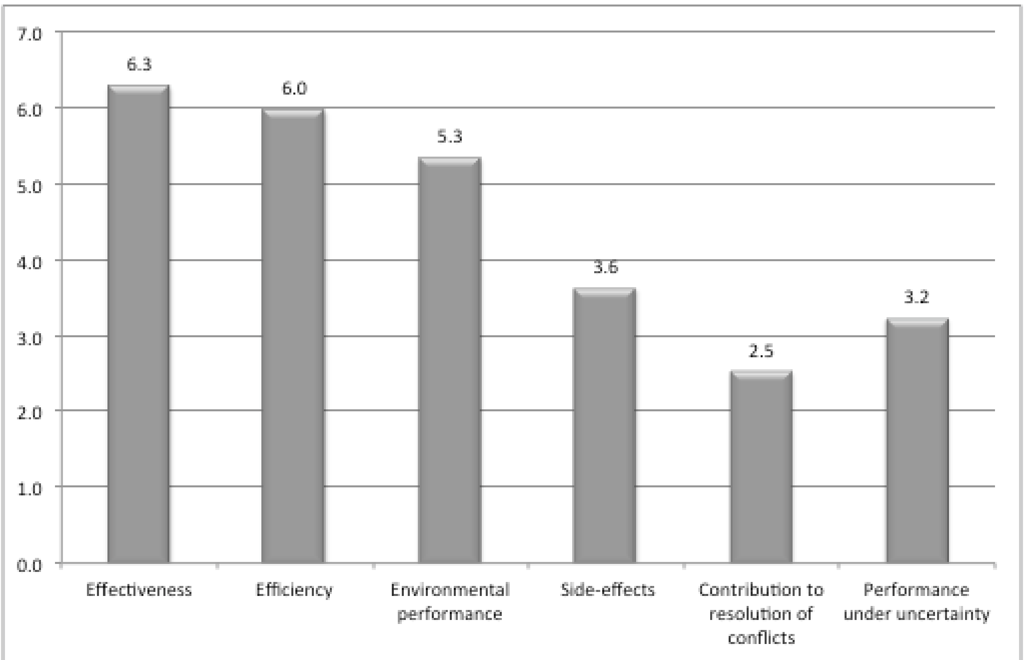

Figure 19: The overall criteria weights

Looking into the results obtained from two subgroups of participants: university students and the invited stakeholders, some differences can be noticed (Fig. 20). Namely, strong preference towards option A – Improving water infrastructures and reducing leakage and E – Improving planning instruments for water saving is noticed among the Val Brenta stakeholders, while students demonstrated preference towards option C - Waste water treatment and reuse.

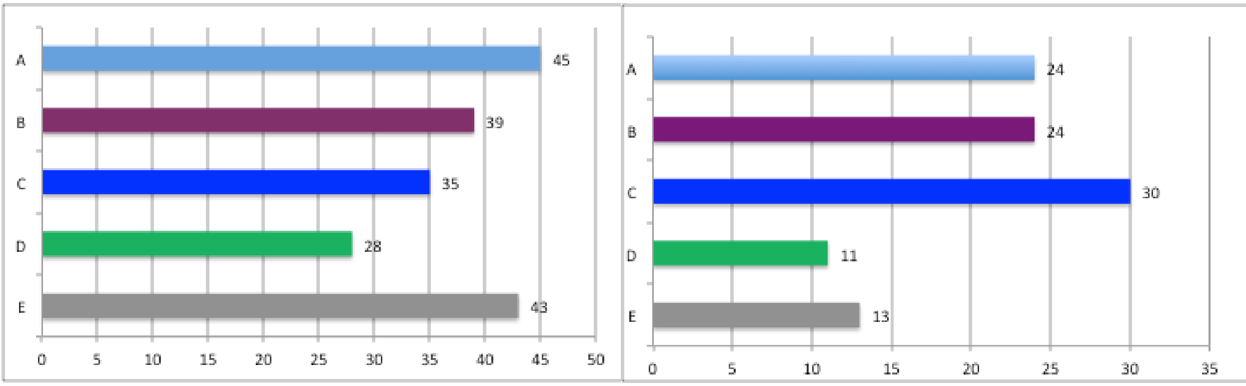

Figure 20: The overall results obtained from the invited stakeholders (left) and a group of university students (right)

The overall criteria weighting was similar in both subgroups (Fig. 21).

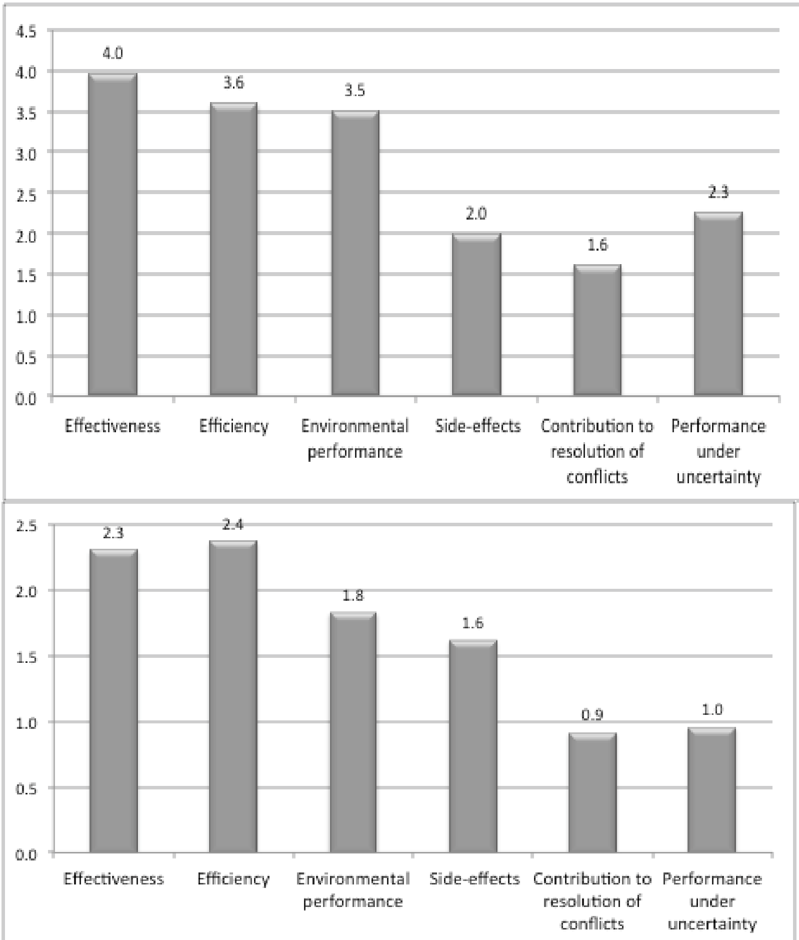

Figure 21 The overall criteria weights for the invited stakeholders (up) and for the student group (down)

4 References

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5 Aknowledgements

We wish to thank all the authorities that provide the required data: ARPAV, Meteotrentino, Fondazione Edmund Mach, Ufficio Dighe Provincia Autonoma di Trento, and ENEL S.p.A. In particular, we also would like to thank the technicians Alberto De Bona, Gianmario Egiatti and Mauro Valt for helping in retrieving some data and solving some operational issues.