ADAPTATION STRATEGIES TO CLIMATE CHANGE FOR THE WATER RESOURCES MANAGEMENT IN THE PROVINCE OF BRESCIA

STRATEGIE DI ADATTAMENTO AL CAMBIAMENTO CLIMATICO NELLA GESTIONE DELLE RISORSE IDRICHE NELLA PROVINCIA DI BRESCIA

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ABSTRACT ESTESO

Fino a qualche decennio fa, l'impatto delle attività umane sulla disponibilità di risorsa idrica era trascurabile e questo ha gradualmente generato e consolidato l'illusione che fosse inesauribile. Dal secondo dopoguerra il suo utilizzo è andato freneticamente aumentando e il crescente inquinamento ne ha compromesso l'integrità in molti casi. E chiaro quindi che anche se l'acqua non è globalmente scarsa, la sua qualità non è scontata: la risorsa idrica che può essere utilizzata per scopi civili senza costosi trattamenti sta diminuendo. L'alterazione del regime pluviometrico in termini di distribuzione, durata e intensità della precipitazione liquida e solida, assieme all'aumento generale della temperatura e la maggiore intensità e frequenza degli eventi climatici estremi, ha avuto conseguenze significative sulla qualità e sulla quantità delle risorse idriche regionali. Per adattare il sistema di gestione dell'acqua alle sfide emergenti, saranno necessari nuovi modelli di gestione basati su approcci di gestione che siano efficienti, sostenibili e che applicano una nuova visione integrata, dinamica, intersettoriale e anche più partecipata, che consideri la continua evoluzione delle condizioni al contorno, anche in relazione al cambiamento climatico.

Il lavoro considera le proiezioni climatiche in termini di precipitazione e temperatura e mira a fornire alcune indicazioni sugli effetti del cambiamento climatico sulla disponibilità di risorsa idrica per la città di Brescia per ottimizzarne le politiche di gestione in vista delle limitazioni nell'utilizzo dell'acqua e la scarsa disponibilità idrica previste per gli anni a venire. Il consumo idrico per la città ha mostrato un decremento fino al 2013, poi ha ripreso ad aumentare ed è previsto che aumenti di nuovo in futuro. Sono state considerate le proiezioni climatiche di alcuni modelli per tre Representative Concentration Pathway RCP (RCP2.6, RCP4.5, RCP8.5) ed è stato valutato il miglior modello da utilizzare per la disaggregazione delle proiezioni alla scala locale. I dati relative ai due periodi 2040-2060 e 2080-2100 mostrano un incremento della temperatura giornaliera che portano a valori più alti di evapotraspirazione. Per la precipitazione i dati mostrano un aumento in inverno e una diminuzione in estate. In termini di deflusso superficiale questo si traduce in una diminuzione, così come in una diminuzione dell'alimentazione delle sorgenti che quindi saranno in sofferenza. L'impatto del cambiamento climatico è più evidente per la sorgente di Mompiano che per quella di Cogozzo. L'effetto del cambiamento climatico è ancora più evidente per la fine del secolo, con disponibilità idrica più scarsa per le sorgenti che attualmente coprono il 14% della richiesta idrica della città.

L'elevato numero di abitanti e le fiorenti attività economiche portano al degrado della qualità dell'acqua, a una gestione difficile delle risorse idriche e del territorio e a un aumento del rischio idraulico e idrologico. Le strategie di adattamento al cambiamento climatico basate sulla pianificazione del territorio mirano sia alla protezione del suolo sia al soddisfacimento della richiesta idrica di diversi portatori di interesse, d'altra parte la gestione sostenibile della risorsa idrica richiede un maggior coinvolgimento delle comunità locali assieme ad un'analisi più dettagliata delle incertezze di scenari climatici futuri e dei loro effetti. Per adattare la gestione della risorsa idrica alle nuove sfide, sono richiesti nuovi modelli basati su approcci di governance che sono efficienti, sostenibili e che applicano una nuova visione che sia integrata, dinamica, intersettoriale e anche più partecipata, che consideri anche la continua evoluzione delle condizioni al contorno, anche in relazione alle sfide climatiche.

ABSTRACT
The aim of this work is to project the climate components of precipitation and temperature to provide some clues on the effect of climate change on the availability of water resources for the water supply system of Brescia and to improve water management and policies since some limitations on the water uses and availability are expected in the upcoming years. The water consumption for the town is showing a decrement from the past till 2013, then it starts increasing again and it is expected to show some more increment for the future period due to the change of the lifestyle and human habits. An evaluation had been carried out for different climate models for three Representative Concentration Pathway RCP (RCP2.6, RCP4.5, RCP8.5) to evaluate the most suitable regional model for the downscaling of future projections. The data for the two study periods 2040-2060 and 2080-2100 show an increment of temperature day by day due to the increment of greenhouse gases and global warming that leads to a higher evapotranspiration. For the precipitation, these data show an expected increment in winter but a decrement in summer. Precipitation and temperature projections lead to a decrease in the amount of surface runoff and of water feeding the springs . Namely, the amount of water that infiltrates and feeds the springs and ground water shows a decrement which will create a pressure on the water resources used for the water supply system. The impact of climate change on the flow coming from Mompiano spring is clearer than the one coming from Cogozzo spring. The effect of climate change will be clearer at the end of this century, showing a decrement of the availability of water from the springs, that are currently covering 14% of the water need of the town.

1. Introduction

Climate change has a direct impact on the water consumption as well as on the water cycle and consequently groundwater and springs (NRC, 2008). In Italy, the volume of total water withdrawn for civil use was 9.5 billion m3 according to the report of the national statistics institute (Istat, 2014), which estimates a growth of 3.8% compared to the figure recorded in 2008. Given competing pressures, global water demand is estimated to exceed by 2030 the actual availability by forty percent (The 2030 Water Resources Group, 2009). Water resources in Italy are 53% located in the north, 19% in the central and 28% in the southern and the islands. Although the percentage of freshwater accumulated in surface waters - lakes and rivers - is relatively small (it is estimated to be approximately 1% of the total freshwater available), they nevertheless constitute an irreplaceable resource since it is in the territories around resources of this type that civilization has often developed. It is therefore in these territories that demand is essentially localized. It may be useful to remember that Lombardy is the richest Italian region in lakes, both in terms of surface (40% of the total) and volume (65%). It is also the most densely populated Italian region. Some of the most important Italian lakes are in the Province of Brescia, some of which are threatened by the heavy anthropogenic loads deriving from the surrounding territories. From this comes the importance of analysing the availability of the water within the province of Brescia focusing on the town, Brescia, as a study area. Brescia is the capital of the province named after it, located at the foothills of the Alps in northern Italy, within the Po River basin and the Italian region named Lombardia providing 16,000,000 m3 of water annually. It has a large reserve of water deriving from the aquifer, the presence of springs and numerous streams, for a water supply system serving 200,000 people. Brescia shows the highest water consumption in Lombardia, with an expected increment for the future, and it hosts several important activities. It lies in the most important industrial area in Italy. Moreover, there are different agriculture activities that are carried out especially in the southern part of the province. Mean annual total precipitation is about 900 mm. Availability of water resource and its proper management are becoming challenging issues due to climate change and population growth.

2. Methodology

The aim of this study was to project discharges observed at the springs feeding the water supply system of Brescia for two future periods 2040-2060 and 2080-2100. Observed climate components of precipitation and temperature for twenty years 2000-2020 were evaluated and analyzed through data taken from the regional environmental agency (ARPA Lombardia), while future data were taken from different regional climate model RCM runs of the CORDEX database for three Representative Concentration Pathway RCP (RCP2.6, RCP4.5, RCP8.5). The climate of Brescia is continental, with cold, damp winters and hot, muggy summers. It is considered as a mid-latitude humid subtropical

climate according to the Köppen-Geiger system (Peel et al. 2007). The average temperature is 13.1°C during the year and the coldest month of the year is January, while the warmest is July. The annual rainfall is about 900 mm.

The domestic water consumption variation was considered for the last couple of years (2004-2019) and changes within the past years were checked.

Finally, a rainfall-runoff hydrologic model was used to simulate the hydrological balance and find the multiple correlation for the two main springs discharge based on the climate model and the data provided from the municipality. Through the rainfall-runoff hydrologic model the amount of actual evapotranspiration was evaluated, as well as the total amount of infiltration into the ground. Then the correlation between the two main springs discharge Mompiano and Cogozzo was found for the two future periods of 2040-2060 and 2080-2100.

3. Results and Discussion

The Brescia Municipality aqueduct, managed by the company A2A Ciclo Idrico, is strictly controlled according to an analysis protocol shared with the ASL in compliance with the provisions of Legislative Decree 31/01 (Legislative Decree No. 31 et al. 2001). The water consumption for the city was showing some decrease from the past till 2014, but this amount started increasing again and it is expected to keep increasing for the future period especially till the end of this century. The past trend is shown in the following (Fig.1). A hydrological analysis has been carried out as well and the results show a small increment of the surface runoff and the evapotranspiration at a yearly scale and a decrement in the inflow, affecting the feed of the groundwater wells and springs. The relation between the precipitation and the spring flow was found and then applied to project water availability under the three emissions scenarios. RCP8.5 shows the highest impact on the availability of the water resources on the two springs for the two periods of study. RCP4.5 impact was close to RCP8.5 for Mompiano spring while the effect of it on Cogozzo is weaker than the one on Mompiano. RCP2.6 shows a general increment of the flow for the two springs of the city under the two periods of study. The source of Mompiano, whose daily production is strongly influenced by meteoric precipitation, in "normal" climatic conditions, delivers about 100 l/s. The two sources of Cogozzo, which are less affected by meteoric precipitation, and they maintain a sufficiently constant production equal to about 35/40 l/s. The whole change of the climate regime needs a management for the available resources. As a summary, the summation of twenty years springs flow in a seasonal scale were evaluated and used to show the impact of climate change on the availability of springs flow under the three representative pathways for the two periods of study. The values of this flow for the springs can be shown in the following (Table 1, Table 2).

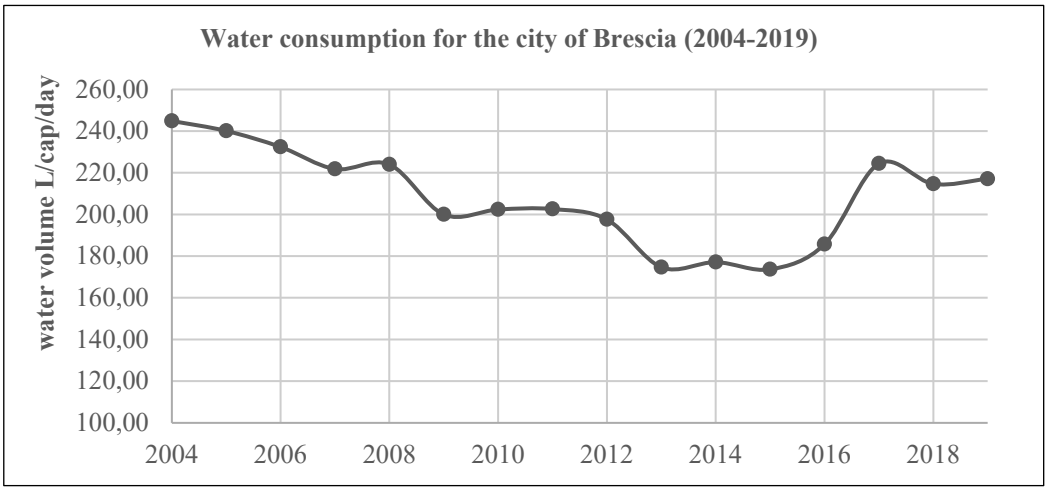

Figure 1 – Water consumption for Brescia
Fig. 1 – *Consumo idrico per Brescia*

Table 1 - Mompiano future seasonal flow (m^3)
Tabella 1 – *Deflusso stagionale futuro a Mompiano (m^3)*

Mompiano future seasonal flow (m^3)				
Data	**Past flow**	**RCP2.6 flow**	**RCP4.5 flow**	**RCP8.5 flow**
Period of study	**2000-2020**	**2040-2060**		
Winter	20180452	24156248	18491231	19945075
Spring	26101302	27566416	26032375	26011288
Summer	27828225	28287095	27546561	27849818
Autumn	20007222	21103279	21132869	23546236
Period of study	**2000-2020**	**2080-2100**		
Winter	20180452	22808362	20296310	20578772
Spring	26101302	26805527	26290669	25390104
Summer	27828225	28150157	28005704	27777079
Autumn	20007222	20794931	21977784	22550154

Table 2 - Cogozzo future seasonal flow (m^3)
Tabella 2 – *Deflusso stagionale futuro a Cogozzo (m^3)*

Cogozzo future seasonal flow (m^3)				
Data	**Past flow**	**RCP2.6 flow**	**RCP4.5 flow**	**RCP8.5 flow**
Period of study	**2000-2020**	**2040-2060**		
Winter	10434234	11013342	10223595	10180558
Spring	10459291	10516265	10464652	10581129
Summer	8982295	9333568	8583249	8674456
Autumn	8695159	8689704	8720611	9828190
Period of study	**2000-2020**	**2080-2100**		
Winter	10434234	10726616	10282523	10767190
Spring	10459291	10551628	10497991	10528243
Summer	8982295	8821150	8789008	8628159
Autumn	8695159	8891114	9191722	9553110

4. Conclusions

A hydrological analysis of water resources availability has been carried out for Brescia. Its results show a small increment of the surface runoff and the evapotranspiration at a yearly scale and a decrement in the inflow, which affect the feed of the groundwater wells and springs. The need of having actions towards climate change adaptation and mitigation is clear. A proper management of water resources available for the water supply system of the town should take into account the projected decrease of the flow coming from springs and its sustainable exploitation in the future years. On the other hand, adopting a knowledge and awareness-based approach for the people may favour a decrease in the water consumption and this would imply working at public-private partnerships and engaging stakeholder and citizens and acting in a flexible approach. Regularly monitor and evaluate adaptation progresses is though essential and in some way accounts for the precautionary principle about the scientific uncertainties, which are there but cannot justify inaction.

Acknowledgements. This research activity is being carried out at University of Brescia in the framework of the national PhD program on Sustainable Development and Climate Change (XXXVII cycle) coordinated by the University School for Advanced Studies Pavia (IUSS).

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