Policy recommendation for drinking water supply cross-border networking in the Adriatic region

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ABSTRACT

Cross-border water resources and drinking water supply management are among the basic concerns for almost all Adriatic Sea countries. Adopting measures such as developing common methodologies, tools and techniques addressing water quality and quantity issues, water losses and pricing policies is a top priority. Regarding the harmonization of procedures and legislative framework, the requirements of the Water Framework Directive 2000/60 are respected. An approach to face these challenges is being developed through the cooperation of several organizations and stakeholders involved in the implementation of the DRINKADRIA project. This paper discusses its specific objectives and outputs linked to: (a) promotion of sustainable provision of drinking water, by setting joint cross-border recommendations on drinking water resources management; (b) undertaking of methods and technologies, through the implementation of pilot actions; and (c) stimulating capacity building, through the exchange of know-how and the development of a regional network of water supply experts. A set of standardized protocols on the applicable management of water supply systems and resources in the Adriatic area is being developed and tested by the beneficiaries involved. The relevant pilot actions aim at improving water supply and water resources management. Eventually, DRINKADRIA's measurable results will support decision makers in the adaptation of effective and efficient measures and policies.

Key words | cross-border, standardized protocols, water losses, water quality trends, water supply

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INTRODUCTION

In the 21st century, around 748 million people globally do not have proper access to drinking water, while approximately one-fifth of the world's population lives in areas facing water scarcity. Furthermore, the global water demand is expected to increase, in several sectors, by 400% within the upcoming 50 years. Consequently, improving policy coherence not only within the borders of a country but also across the cross-border (CB) area will be one of the top priorities in the water sector, within the forthcoming period (UN World Water Development Report 2015). EU Member States are obliged to manage their water resources following the principles of Water Framework Directive (WFD 2000/60/EC). The latter obliges Member States to cooperate when transnational river basins are identified. Specifically, 40 (out of the 110 in total) river basins are identified as transboundary, covering more than 60% of the EU territory (CEC 2007).

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Water supply and resources management within the borders of a country is an extremely complicated process, which policy makers and experts are called to effectively face. Several aspects, such as water quantity and quality, available resources, temperature, water pressure, asset ageing, fluctuating demand, operation and maintenance risks, leakages, accidental pollutions, pipe bursts, soil instability, pricing policies and supply standards should be recognized and analysed, to meet the required objectives and goals set. Regarding the CB water supply and resources management, the aforementioned complexity is 'multiplied by several times', as no standard and common methodologies, procedures and techniques exist. Specifically, within the borders of the Adriatic sub-region, drinking water supply and resources management is historically bound to tight CB cooperation, as political changes determined the level of synergy among the countries involved, during the last decades. DRINKADRIA project stakeholders' (Drinkadria Handbook 2014) joint actions are called to narrow this gap, between two or even three neighbouring countries, located in the Adriatic sub-region. Its principal objectives are conceptualized on the basis of recognized common and trans-boundary problems, related to the water supply in this region. Climate change (CC) is also taken into consideration as a major factor affecting water resources and water supply systems (WSS).

The DRINKADRIA project involves 17 partners from eight countries in the Adriatic region. The project's duration was 35 months and it was concluded at the end of September 2016. The DRINKADRIA project aims at developing a base for strategies and procedures for secure CB water supply with specific emphasis on water resources management in a CB and cross-regional context, CC and specific socio-economic aspects of the Adriatic region. The project's objectives include: (a) effective and efficient management and protection of CB water resources and water supply; (b) analysis of the CC impacts to water resources quantity and quality, estimating also their vulnerability; (c) reduction of water losses in WSS and efficient long-term management of the water supply network; and (d) suggestions regarding the effective drinking pricing policy especially when CBWSS are identified. The present paper aims at presenting the work elaborated during the project and its most important outcomes. Many aspects are discussed, such as CC impact to water resources quality and quantity; assessment of water resources status in terms of quantity (examining also climate conditions and CC impact on them) and quality; safety of water resources used for drinking water; and costing and pricing policies of drinking water, especially when CB water resources are involved. The paper also presents the pilot actions implemented during the project regarding both water quantity and quality. The CB cooperation of DRINKADRIA partners along with the capitalization activities proved to be a unique opportunity for efficient and effective CB water supply and water resources management. The paper's structure follows the project's structure to be more comprehensible.

CB COOPERATION INTRODUCING A UNIQUE OPPORTUNITY

Background, problems and challenges

Water supply domain in the Adriatic sub-region is characterized by: ageing infrastructure; high non-revenue water levels (water not bringing revenues to the water utility due to water losses and not billed water consumption); and CC and increasing water demand, induced mostly by the tourism sector. Tourism activities are also inducing high seasonal fluctuations in water demand, within the same area. Based on the problems identified in the region, CB water supply management and shared trans-boundary water resources management are the basic objectives of the DRINKADRIA project (Drinkadria Handbook 2014; Kanakoudis et al. 2015).

Although European legislation exists, the problem of CB water resources management still remains a challenge. The WFD provides, on the one hand, necessary guidelines for CB cooperation in the field of water resources management, while on the other hand no comprehensible legal framework exists for CB water supply management, letting it become a subject of negotiations at national and regional levels regarding the quantity and quality of water, supply dynamics, and short and long-term planning and maintenance. The aforementioned CB negotiations are currently being carried out without a common conceptual and institutional framework.

Existing WSS occasionally are not managed properly, resulting in deteriorated CB water resources quality. In extreme cases, to avoid any potential conflict between the countries involved, these WSSs are not managed at all. The issue of efficient and effective CB water supply and water resources management is being addressed in its complexity, while a set of standardized protocols for the pertinent management of WSS and resources (mainly groundwater in the Adriatic area) are developed. Participating organizations in the DRINKADRIA project, along with local stakeholders, are called to validate these protocols, supported by the implementation of applicable pilot actions aimed at two core domains: water quality and water quantity. Through the improvement of water supply and water resources management, water utilities involved in the DRINKADRIA project will become more efficient throughout the entire water supply chain, to guarantee sufficient and good-quality water quantity. Moreover, the contribution of each water utility to the environmental damage and depletion of natural reserves of the related River Basin District is being calculated (Kanakoudis *et al.* 2011).

Advanced communication, dissemination and results' capitalization activities empower the efficiency of the DRINKADRIA project outputs and results. Capitalization of experiences is two-fold. On the one hand, national events in the countries involved engage those stakeholders that are significant for CB/regional WSSs, while on the other hand, project inputs serve as a basis for protocol development. Additionally, the use of several tools and techniques aims at sustaining the project's results beyond the project's ending point, through the cooperation of the partners with associated partners and stakeholders, and by establishing a networking electronic web-based platform. Given the innovative character of the project, lessons learnt and best practices are spread among stakeholders through the capitalization activities. It is the first time that CB water resources and water supply management have been addressed both from the side of water resources and from the side of drinking water supply.

CB networking

DRINKADRIA's partnership scheme is a well-harmonized set of stakeholders, located in the Adriatic area, with an optimal combination of four regional authorities, five water utilities, seven research organizations, and one water supply and sewage national association. Seventeen partners from eight countries, namely Italy, Slovenia, Croatia, Serbia, Albania, Bosnia and Herzegovina, Montenegro and Greece, are involved (Kanakoudis *et al.* 2015). Four types of associate partners are also involved (governmental bodies, regional/local authorities, water supply associations and end users), acting as 'supervisors' of the project's activities. The target groups are the residents of the involved countries, the public institutions such as hospitals and schools, and certainly tourists. Activities and results have a significant impact within the entire Adriatic area and the rest of Europe, through the development of practical protocols addressing a wide spectrum of issues to be determined and established for CB water supply and water resources management (WRM). Besides, the fact that only a limited number of CB water supply agreements globally exists was one of the driving forces for the project idea.

Coherence with national and European policies

The DRINKADRIA project contributes to the development of joint CB strategies (and measures) of WRM and drinking WSS, along with the preparation of a common code with good practices for water utilities. During the project, the promotion of sustainable provision of drinking water by stabilizing water demand, through the elaboration of future plan scenarios on drinking water demand and supply, joint CB recommendations on management of water resources (quality and quantity) and measures for reducing water losses and wasteful/non-sustainable consumption have been addressed. An additional task is the stimulation of capacity building through the exchange of know-how, the development of a regional platform (network) of water supply stakeholders (utilities, authorities and research institutions) and the sharing of knowledge regarding WSS optimization.

Both Lisbon and Gothenburg agendas/strategies are integrated in DRINKADRIA's activities, since efficient water service provides a backbone for the competitiveness of the EU economy considering sustainability of water supply. Management options for mitigating water resources vulnerability contribute to the environmental sustainability.

DRINKADRIA recommendations in water supply services aim to ensure future water availability and safety, from which consumers will benefit. The effective cooperation is also taking into consideration EU Drinking Water Directive 98/83/EC, EU Critical Infrastructure Directive 2008/114/EC and CSN EN 15975-1: Security of drinking water supply requirements and guidelines. According to the EC 'Blueprint to Safeguard Water Resources' (European Commission 2012), significant improvements in the water sector are also necessary to ensure availability of good water quality for sustainable and equitable water use. CC, land use, economic activities such as energy production, industry, agriculture and tourism, urban development and demographic change are the main causes of negative impacts on water status. This means that the ecological and chemical status of EU waters is threatened. The water resources may become more vulnerable to extreme natural disasters such as floods and droughts. Therefore, it is essential to address these challenges to preserve the resource base for life, nature and the economy. DRINKADRIA is called to address a series of WRM issues regarding the insufficient use of economic instruments, lack of support for specific measures, poor governance and knowledge gaps.

Approximately, within half of EU Member States, more than 20% of clean drinking water is lost in the distribution network, while in some Member States this indicator almost reaches 60% (European Commission 2014). For this reason, enforcement actions, such as DRINKADRIA pilot actions aiming at the reduction of high level water losses and non-revenue water, are essential. The gained experience has positive effects on future WSS management, particularly for the foreseen regional WSS. Transnational cooperation is necessary due to the fact that there are many surface and groundwater bodies located over two or even more participating countries. Efforts to deal with these issues need to be coordinated jointly, facilitating the identification of common problems and application of appropriate adaptation measures. Effective strategies for safe CB water resources, managing at the same time drinking water demand and supply in a CB context, could be the 'benchmark' of the legislative framework, ensuring sustainable long-term CB water supply. These results could be also applied in other regions on a European and a global level.

THE METHODOLOGICAL APPROACH: CB WATER RESOURCES AND WATER SUPPLY MANAGEMENT

A standardized methodological approach has been formed to develop a database for water quality, quantity status and effects of CC on water resources, followed by the determination of water resources availability, quality and safety assessment, as a basis to evaluate vulnerability-risk-hazard levels of water resources. The determination of driving forces and competing influences on water resources, with impacts on water supply, is followed by the preparation of CB operational protocols and common decision support system (DSS), enabling efficient long-term drinking water supply.

The DRINKADRIA project's measurable outputs and related results are linked to CC impacts on water resources and drinking water supply, through the identification of adaptive measures, and target group's awareness of CC impacts on drinking water supply. Common methodologies for water resources vulnerability, risk and hazard assessment and water protection areas determination, along with the elaboration of measures and proposals on legislation harmonization for CB water resources protection, have been prepared along with the protocols for CB water resources and supply management.

The methodology followed during the project implementation consists of the following steps: (a) CB WRM; (b) CBWSS management; and (c) pilot actions. More specifically, the CB water resources management consists of four activities: climate characteristics and CC analysis; water resources availability assessment; future water safety and risks analysis; and water resources protection. CBWSS management consists of: historical overview of CB water supply; analysis of existing and potential CB cooperation; protocols and procedures development for CB water supply; and economic model development. Finally, pilot actions have been implemented regarding reduction of non-revenue water (NRW) and improvement of water quality.

The regionalized activities being implemented in pilot areas represent different environmental and socio-economic characteristics in the Adriatic area. The development of a sharing knowledge platform is expected to achieve the maximum sustainability of outputs and results. DRINKADRIA outputs have been processed in the form of reports, maps, guidelines, joint tools and management proposals, compiled in a comprehensive booklet and widely disseminated to the general public and relevant stakeholders, who directly or indirectly have benefited or will benefit through the improvement of water resources and supply management techniques and the integration of innovative technologies (advanced hydraulic model of WSS, water loss reduction practices and District Metered Areas formation for effective pressure management). The web-based communication platform is being and will be used for continuous exchange of experiences, targeting the continuously increased number of end-users (water suppliers) benefiting from innovative technologies for water efficiency use and water quality improvement. This platform provides a DSS for preserving limited water resources, improving water supply efficiency and capacity building. The water governance analysis and enhancement of participatory framework in the countries involved, with identification of gaps and suggestions for possible improvements, are also priority listed in 'Blueprint to Safeguard Europe's Water Resources'. The regional drinking water supply economics model is serving as an analysis tool for performance assessment of WSS and for several scenario evaluations.

CB water resources management

CC is considered as a major threat for the sustainability of water resources and water supply, mainly due to the fact that climatic characteristics (temperature and precipitation) are already affected (Arnell *et al.* 1996; Kaczmarek *et al.* 1996; Hewitson & Crane 2006; Chung *et al.* 2011; Jun *et al.* 2011). Many studies consider that future climate conditions cannot be predicted based on the analysis of historical climate characteristics indices (Georgakakos *et al.* 2012). Instead, future CC impacts on water resources should be estimated. As CC is expected to affect water resources in many different ways, adaptation measures need to be taken to reduce water crises' implications in the future (Gutiérrez *et al.* 2014; Sisto *et al.* 2016). Thorough assessments on water resources and water supply vulnerability, water scarcity estimation and drought analyses are necessary tools. Water resources vulnerability is a complicated issue, taking into consideration many different factors (natural and human), such as water availability and quality, pollution, population growth, competition over water and knowledge gaps (Brooks *et al.* 2005; Hamouda *et al.* 2009). Gleick (1990) connected water resources vulnerability to CC. Many studies refer to CC impacts to water resources; however, it is difficult to quantify these impacts. Many indicators have been developed since then, such as environmental and water-related indicators (Rogers *et al.* 1997; Lane *et al.* 1999), while an integrated water resources vulnerability index was formed based on hydrologic and socio-economic indicators (Raskin *et al.* 1997). A flood vulnerability index was developed comparing vulnerability among river basin, sub-catchment and urban areas (Balica *et al.* 2009). Both climatic and non-climatic factors affecting water resources vulnerability were studied in two cases in Pakistan (Shabbir & Ahmad 2015). Studies by Collet *et al.* (2015), Haque *et al.* (2015) and Meuleman *et al.* (2007) investigated measures and strategies for drinking water supply.

Climate characteristics and CC

It is stated that changes in physical processes in the global hydrological cycle over the past 50 years may be linked to CC. More specifically, changes in climate have caused impacts on natural and human systems on all continents, indicating the sensitivity of natural and human systems to CC (IPPC 2014). In order to be able to analyse the available water resources in the Adriatic sub-region, the DRINKADRIA partnership reviewed the existing climate and CC data (observed data) and estimated the trends of future climate and CC using different climate models for the future. The partnership also prepared a database of climate and CC observed data (1961–1990) and estimated (modelled) data (precipitation and temperature) for the years 2021–2050. Such a database is useful in developing a common platform to exchange, compare with water resources availability-related data and use it in a trans-boundary context. Reports on climate and CC data are developed initially at national/regional level and then at test area level for all countries involved. Using different climate simulation models and scenarios, CC trends in future period(s) are described. All countries involved reported on the steps they are taking in order to implement the UNFCCC (UN Framework Convention on Climate Change, Articles 4.1 and 12). The DRINKADRIA reports at national level for most countries are based on National Communications under the UNFCCC (2014), with additional information from other national studies, documents and published papers (all references are given in national reports). To simulate future climate characteristics, SRES (Special Report on Emissions Scenarios) scenarios are used. The IPCC (Intergovernmental Panel on Climate Change) published a set of SRES scenarios in 2000 for use in the Third Assessment Report (IPCC 2000). A variety of SRES scenarios with several assumptions regarding driving forces is being used. The six scenario groups – the three scenario families A2, B1, and B2, plus three groups within the A1 scenario family, A1B, A1FI, and A1T – and four cumulative emissions categories were developed as the smallest subsets of SRES scenarios.

In some reports the impact of CC on water resources is analysed. The data included are used in the following activities, for the analysis regarding water resources quantity and quality vulnerability.

Based on data regarding observed climate and CC characteristics at national and regional levels, it can be concluded that an increase of temperature has been observed in the countries involved (Kanakoudis *et al.* 2016). Negative trends are observed only in certain periods, specifically within the territories of Serbia and Albania (Table 1). In general terms, changes in precipitation levels differ from country to country. In Italy (Marche Region), Serbia and Greece (islands of the Ionian and Aegean Sea) a reduction in precipitation has been observed (Kanakoudis *et al.* 2016). In other countries (Slovenia, Croatia, Bosnia and

Table 1 | CC characteristics in the Adriatic region (national/regional level) (DRINKADRIA 2015a)

Country	Period	Temperature	Precipitation
Italy (Marche Region)	Observed data: 1950–2000	Annual trend: increasing ranging between 0.5 and 1.3 °C (maximum values) and 0.8 and 1.7 °C (minimum values)	Decreasing trend and determination of a reduction more than 10% and reduction of the average rainfall of about 5 mm/year
Slovenia	Reference period: 1971–2000	Average increasing across the whole country	Autumn rainfall increases almost across the whole country. Winter precipitation decreases across western Slovenia. No changes in eastern Slovenia
Croatia	Observed data: 1981–2010 Reference period: 1961–1990	Increasing with the highest trend ranging between 0.3 and 0.4 °C per decade (maximum values) and 0.2–0.3 °C per decade (mean values)	Annual precipitation increasing in the eastern lowland (8–11%) and decreasing in the rest of the country (–7 to –2%)
Bosnia and Herzegovina	Observed data: 1981–2010 Reference period: 1961–1990	Increasing ranging between 0.4 and 0.8 °C	Slightly increasing trend annually. Largest decrease during spring and summer in Herzegovina (up to 20%)
Montenegro	Observed data: 1949–present	Increase in northern mountainous region of +1.4 °C and coastal region of +1.3 °C in period 2001–2010	No tendency to increase or decrease, except in the northeast, where precipitation increased
Serbia	Observed data: 1949–2006	Highest increase in spring (1.5 °C/100 yrs) in winter (0.5 °C/100 yrs). In autumn there is a negative trend (0.7 °C/100 yrs)	Negative annual average trend. Lowest negative trend is from –5–0% /100 yrs in Central Serbia
Albania	Observed data: 1931–2000	During the end of the first half of the 20th century there was an increase by 1 °C. During the third quarter a cooling of 0.6 °C. The rest of the period there is an increase by 1.2 °C	Spatial variation on a country level. Decreasing trend in the test area
Greece	Observed data: 1949–2006 Reference period: 1961–1990, 1991–2000, 2001–2013	Since the 1990s annual increase is observed of about 0.4–0.6 °C	Decreasing trend (in the islands of the Ionian and Aegean Sea). In Corfu there is an unstable fluctuation during 1980–2001

Herzegovina, and Montenegro) unstable levels of precipitation are observed, indicating that both a decrease and an increase of precipitation are observed, depending on the season and the study area (Table 1).

Based on data regarding climate and CC, simulations of future scenarios at national and regional levels are described in each partner's report (Table 2). It could be concluded that an increase in temperature is predicted in all eight countries involved in the DRINKADRIA project. The levels of temperature increase vary from country to country, depending on the SRES scenario, the season of the year, the study area of the country, etc. Regarding the precipitation, changes vary depending on the season, and on the specific region of the country. It is important to mention that there are cases (such as Albania) where precipitation decreases, while the number of days with heavy precipitation increases. Also, in Greece for example, the number of intense precipitation phenomena increases. Different SRES scenarios and different climate simulation models are used for the CC simulations. In Slovenia, the SRES scenarios used are A1T, A1FI, A1B, A2, B1 and B2. In Croatia, Serbia, Bosnia and Herzegovina, and Montenegro, scenarios A1B and A2 are being used. In Albania, the category of scenario is not specified for the three analysed periods and in Greece, scenario A1B is being used. The exact models used for climate simulations in the Adriatic area on national and regional level are: PROTHEUS regional climate model (RCM), Aladin, PROMES, RegCM, EBU-POM, GFDL-ESM2M and RACMO2 (Table 2).

Climate characteristics and CC prediction was also performed at test area level. Nine test areas are identified. The analysis results showed that temperature is predicted to increase in all test areas, with differences in predicted increase level due to different regional climate models used. Precipitation trends are diverse, depending on the selected station, climate model and time series used. Precipitation predictions are found to be less reliable. The analysis attempts to review climate data already observed at regional/national/test area level and identify climate trends in the future based on several climate models. Further analysis is required to predict the likelihood of these changes occurring in the future. It must be stressed that models' simulations of the future climate should be interpreted as projections of the possible state of the climate system, being sensitive to many other factors (such as greenhouse gases scenarios, etc.).

Water resources availability

The second activity performed during project implementation was the analysis of water resources availability risk, focusing more on drinking water use. The methodological approach used consists of three parts: (a) analysis of the impact of CC on renewable water resources; (b) evaluation of water demand; and (c) calculation of water exploitation index (WEI). The data from the first activity (described above under 'CB water resources management') were used. Regarding surface runoff and recharge, the data collected were basic hydrological information to determine the renewable water resources characteristics. In order to understand the impact of CC on those resources, the relevant changes are analysed along with the alterations in the hydrological basis (long-term averages of the total runoff, spring rate or recharge). Basic hydrological information for the evaluation of the CC on water resources for long-term averages on test areas is analytically presented (Table 3).

More specifically, in Italy the highest change is predicted in Ostuni-Ionic area, while in Croatia it is observed in Northern Istria-spring Bulažarea, and in Albania in Drini basin-Drini of Lezha, using the PROMES model (Figure 1). In general, the most significant decreases in precipitation are observed in the southern areas of the Adriatic region, resulting in a stronger reduction in terms of water availability.

The second step included the water demand evaluation in the test areas (total water use and drinking water use, for present and future time periods). The collection of all those data led to the third step, which is the WEI estimation, to assess the water resources availability risk. The WEI is the ratio of water demand (including all uses) to renewable water resources. Three scenarios for water demand are analysed: (a) scenario 0: present water demand; (b) scenario 1: future water demand increased by 25% compared with the present one; and (c) scenario 2: future water demand decreased by 25% compared with the present one. Then, four different combinations of water demand scenarios and renewable water resources are analysed (Kanakoudis *et al.* 2016). WEI1 refers to present water demand and present

Table 2 | Climate and CC simulations for future scenarios in Adriatic region (national/regional level) (DRINKADRIA 2015a)

Country	Model	SRES scenario	Reference period	Time period	Temperature	Precipitation
Italy (Marche Region)	–	–	–	–	Increase in the future	Decrease in total annual rainfall
Italy (Apulia Region)	PROTHEUS RCM	Not specified	1953–2000	2001–2050	Increase mostly during the period between early spring and late autumn	The global trend of decreasing is not confirmed over the whole case study. There is a monthly variation
Slovenia	Four MSC methods	A1T, A1FI, A1B, A2, B1, B2	1961–1990	2001–2090	Increase depending on the selected emission scenarios. 2001–2030 temperature is expected to rise by 0.5 to 2.5 °C, 2031–2060 from 1 to 3.5 °C, and 2061–2090 for 1.5 to 6.5 °C (for Ljubljana)	Changes in annual precipitation range from +10 to –30%
	CC-waterS: three RCMs (Aladin, PROMES and RegCM)	A1B	1961–1990	2021–2050, 2071–2100 (models used: Aladin, RegCM). 2021–2050 (model used: PROMES)	Increase on average more than 3 °C	High degree of ambiguity, less precipitation in the summer. Increase in autumn
Croatia	RegCM	A2	1961–1990	2011–2040	Increase winter temperature of 0.6 °C, summer 1 °C	Decrease in Adriatic in autumn with a maximum of approximately 45–50 mm in the southern Adriatic
	RegCM	A2	1961–1990	2041–2070	Increase winter up to 2 °C in continental part	Decrease in the mountainous and in the coastal area of 45–50 mm
	Various RCMs (18 combinations)	A1B	1961–1990	2011–2040	Increase of T2 m air temperature in all seasons from 1 to 1.5 °C	Increase in Kvarner region by 5–15% (relative to 1961–1990). Decrease (–5 to –15%) in the southern part during spring
Bosnia and Herzegovina	EBU-POM, SINTEX-G & ECHAM5	A1B	1961–1990	2001–2030	Increase ranging from +0.6 to +1.4 °C	Increase during spring from +5% and during summer up to +15%
		A1B		2071–2100	Increase ranging from +1.8 to +3.6 °C	Decrease in winter and autumn from –10 to –50%
		A2		2071–2100	Increase ranging from +2.4 to +4.8 °C	Decrease during summer up to –50%

Montenegro	EBU-POM	A1B	1961–1990	2001–2030	Increase from 0.6 to +1.3 °C	Negative (up to –10%) and positive (up to 5%) changes depending on the part of the country and the season
		A1B		2071–2100	Increase from 1.6 to +3.4 °C	Central parts decrease up to –30%
		A2		2071–2100	Increase up to +4.8 °C	Largest decrease along the coast up to –50%
Serbia		A1B	1961–1990	2001–2030	Average increase annually +1 °C	Change from 5 to +5%
		A1B, A2		2071–2100	Increase annually +2.5 and +3.7 °C	Decrease up to –15%
Albania	GFDL-ESM2M	Not specified scenario	1980–2004	2025–2049	During winter increase of 3 °C and summer 4 °C	Max decrease of precipitation of approx. 5–6 mm in the southern Adriatic.
				2050–2074	During winter increase of 4 °C and summer 4.5 °C	Decrease of 5–6 mm. Increase in north-western Albania and on the Adriatic
				2071–2095	During winter increase of 6 °C and summer 6.4 °C	
Greece	RACMO2	A1B	1961–1990	2021–2050	Mean min winter temperatures will be ~1.5 °C higher in 2021–2050. In mountainous areas, temperature increase will reach 2 °C. The increase in mean max summer temperatures will exceed 1.5 °C and in some cases reach 2.5 °C	In the eastern continental regions, maximum consecutive three-day precipitation is projected to increase by 20%
				2071–2100	Mean min winter temperatures will be ~3.5 °C higher in 2071–2100. In mountainous areas, it is projected to reach 4 °C. The increase in mean max summer temperatures may go up to 5 °C (excluding regions with strong sea breezes)	Decrease by 10–20% in Western Greece and increase by 30% in Eastern Central Greece and NW Macedonia

Table 3 | Basic hydrological data for the evaluation of the CC on water resources in average conditions for test areas (DRINKADRIA 2016a)

		Long-term average (m^3/s)				**Changes compared with baseline (%)**		
			2021–2050			**2021–2050**		
Country	**Test area**	**1961–1990**	**RegCM3**	**Aladin**	**PROMES**	**RegCM3**	**Aladin**	**PROMES**
Italy	Isonzo plain	41.6	44.2	49.3	37.7	6.3	18.5	–9.4
	Ostuni – Adriatic	6.23	5.81	4.84	4.61	–6.7	–22.3	–26.0
	Ostuni – Ionic	5.24	4.86	4.80	3.46	–7.3	–8.4	–34.0
Croatia	Northern Istria – spring Gradole	2.17	2.13	2.08	2.00	–1.9	–4.1	–7.8
	Northern Istria – spring Sv. Ivan	0.92	0.92	0.86	0.60	–0.3	–6.5	–34.9
	Northern Istria – spring Bulaž	1.70	1.56	1.55	2.22	–6.3	–8.8	30.8
	Southern Dalmatia – Prud	6.16	5.60	5.39	5.01	–9.1	–12.5	–187
	Southern Dalmatia – Blatskopolje	0.287	0.259	0.235	0.222	–9.8	–18.1	–22.6
Montenegro	Niksic	1.26	0.88	0.89	0.86	–30.2	–29.4	–31.75
Albania	Drini basin – Drini river	(1951–1985): 360	340	310	290	–5.6	–13.9	–19.4
	Drini basin – Buna river	(1951–1985): 320	305	290	275	–4.7	–9.4	–14.1
	Drini Basin – Drini river +Buna river	(1951–1985): 680	645	600	565	–5.1	–11.7	–16.8
	Drini basin – Drini of Lezha	(1951–1985): 30	27	25	22	–10	–16.7	–26.7
Greece	Corfu – GR0500010	2.38	1.78–2.97			–25 to +25		
	Corfu – GR0500020	1.27	0.95–1.59			–25 to +25		
	Corfu – GR0500030	1.27	0.95–1.59			–25 to +25		

renewable water resources (1961–1990); WEI2 refers to present water demand and projected renewable water resources (2021–2050); WEI3 refers to future increased water demand (+25% compared with present one) and projected water resources (2021–2050); and WEI4 refers to decreased future water demand (–25% compared with present one)

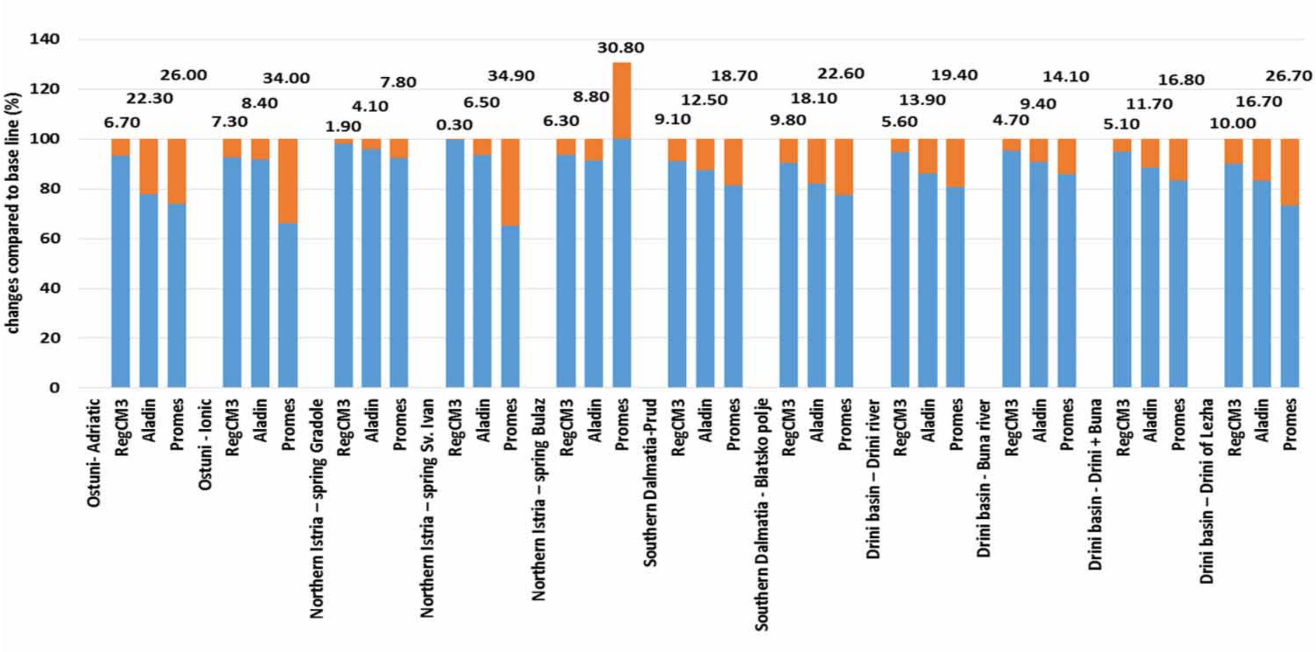

Figure 1 | Changes in average flow and recharge for future period 2021–2050 compared with 1961–1990 baseline period.

and projected renewable water resources (2021–2050) (Figure 2). The following classification regarding WEI values was used: WEI values $\leq$0.50 show low risk; WEI values between 0.51 to 0.70 show possible difficulties; WEI values between 0.71 to 1.00 show strong risk; and WEI values >1 show a not sustainable situation (Figure 2).

From the analysis, it can be concluded that CC will have an impact on water resources availability in the future period 2021–2050, decreasing available water resources quantities. The evaluation of water demand and calculation of WEIs according to the common methodological framework showed different water availability risks at the test areas. The results provided a better understanding of the CC impact on water resources in the Adriatic region, as well as possible risks of deterioration of water supply possibility from those resources. The scenario analysis targeted identifying future possible problems and proposing and implementing appropriate measures in time. The partnership developed a hydrological database including data for estimating water resources availability and data about the whole Adriatic region, by country and by test area.

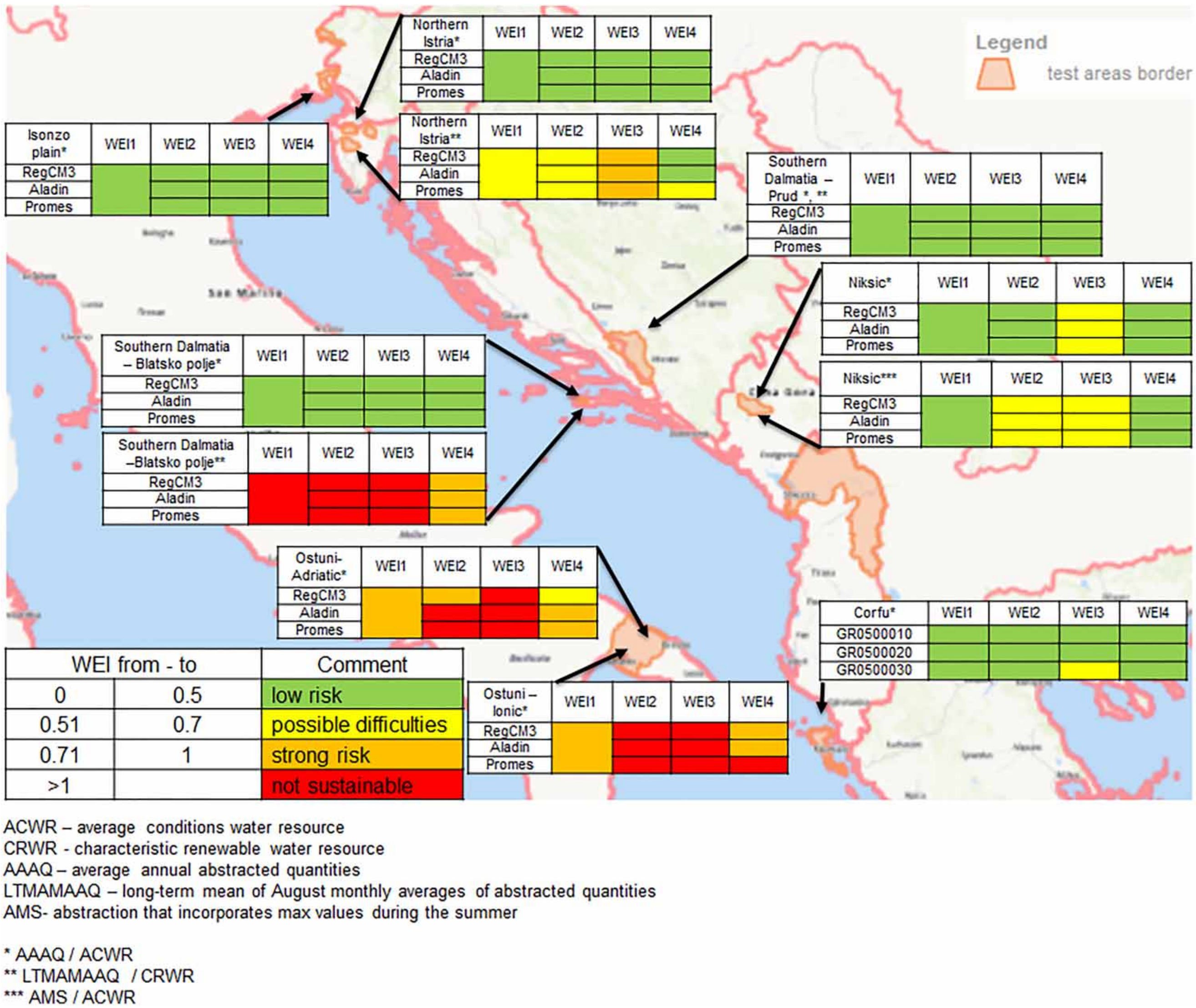

Figure 2 | WEI index for different scenarios in the test areas.

Water quality analysis and trends and water safety

Another basic activity of the DRINKADRIA project is basically focused on determining water quality indicators and evaluating the parameters related to the drinking water quality deterioration within the pilot areas (Table 4). The main tasks are the determination of the existing land uses' impact on water quantity and quality (impact-effect matrix), the trends in water quality, the future water safety regarding changing land uses, the analysis of salt water intrusion issues and the possibilities of drinking water quality improvement (artificial recharge and measures to improve the quality).

The analysis was performed in different types of water resources, namely groundwater, surface water and spring water. In groundwater bodies, the main water quality problems identified include high concentrations of nitrates (Isonzo plain, Corfu) and chlorides (in some cases in Corfu) and groundwater salinization (Ostuni). Increased concentration of sulphates was identified (Isonzo plain, Corfu), but in some cases they are due to gypsum presence underground (Corfu). Regarding surface water, increasing trends of BOD (biochemical oxygen demand) were observed in certain cases in Serbia and Albania, nitrogen shows an increasing trend (in Ohrid lake – Albania) and high oxygen saturation values are observed (Bosnia-Herzegovina). Nitrates show an increasing trend in certain cases in Serbia and Albania. Also, increased concentrations of copper, total chromium (Bosnia – Herzegovina) and phosphorus (Albania) are observed. Spring water quality analysis showed increased turbidity (Montenegro) and mild microbiological contamination (Croatia, Bosnia-Herzegovina, Montenegro), while in other springs an increasing trend of total suspended solids is observed (Croatia, Slovenia).

The next step included the analysis of the present land uses, the analysis of the CC impact on the land use in the future, and the analysis of the land use impact on water quality. Corine land cover was used for determining the present land use and the land use changes. Specific proposed measures have also been reported.

As the project was focused on CB water resources, their water quality and safety are of great importance, as water meets no frontiers. During the implementation of the project, an investigation was performed regarding water safety tools used by the different partner countries. The results showed that there are different approaches regarding water security and safety among the countries. In some countries HACCP (Hazards Analysis and Critical Control Points) and WSP (Water Safety Plans) are obligatory, while in others they are not. In some countries, it is the water utility's decision whether or not to adopt such a tool.

CBWSS management

Historical development of CB drinking WSS

An overview of the historical development of CB drinking WSS in the Adriatic area has never been implemented before. Through DRINKADRIA activities, a systematic data collection took place. These data focus on the identification of: (1) general data; (2) legal framework; (3) CBWSS economics; (4) technical issues; (5) management issues; (6) Shapefile files; and (7) methodologies and tools. All collected data are uploaded into the DRINKADRIA web platform (http://drinkadria.fgg.uni-lj.si/) (Figure 3). The analysis of water demand trends is playing a key role in long-term planning of WSS development. Multiple factors are considered in this analysis, such as: (1) growth/decline of population; (2) growth/decline of tourism (there is an issue regarding the seasonal dynamics of water supply during the peak summer season); (3) growth/decline of industry and growth/decline of agriculture. Guidelines are prepared for the development of a systematic analysis framework, regarding the experiences from the WSS involved. A catalogue of criteria is considered: (1) the population served; (2) the state of infrastructure; (3) the financial sustainability of WSS and the financial resources reserved for maintenance; (4) the significance of the tourism sector, industry and agriculture impact; and (5) the long-term programming of WSS in CB context. A pricing model is proposed to be used in CB water supply cases. The model is based on cost items in the water supply, such as pumping, water treatment and water distribution. The costs are allocated as variable and fixed (stable) costs (DRINKADRIA 2016b).

The data provided by DRINKADRIA beneficiaries after being elaborated are uploaded into a web-based geographic

Table 4 | Basic water quality indicators and trends in DRINKADRIA test areas (DRINKADRIA 2016c, 2016d)

Country/test area	Basic water quality characteristics and trends	Land use
ITALY: Friuli Venezia Giulia – Isonzo plain	Nitrate content on pumping wells had always quite low concentrations (<15 mg/L) over a legal limit of 50 mg/L. A fossil marine aquifer is present in the depths in the carbonates; therefore, the high chloride values in the northern wells can be linked to this resource and not to the salt water intrusion. The general sulphates trend is quite constant, slightly increasing within the last years for two wells, but below the legal limit. The analyses showed a complete absence of any kind of micro-organisms	Agriculture 58.81%, urbanized area 22.48%, natural environment 10.5%, water surface 3.56%, industry 3.14%, sport and leisure 0.94%, quarry and landfill 0.57%
ITALY: Marche Region – ATO3	Very rich mountainous area in terms of aquifers, potentially providing large volumes of good quality water. Progressive worsening in the valleys (medium-high hilly area and flat-coastal zone) of water quality features: electric conductivity between 600 and 1,400 μS/cm, dry residue between 0.3 and 0.8 g/L. Significant increase in nitrates concentration	Calcareous ridges: agriculture 35%, forestry 63%, artificial surfaces ~1%, water bodies ~1%. Alluvial plains: agriculture: 77%, forestry 16%, artificial surfaces 6%, water bodies <1%
ITALY: Apulia Region – Ostuni	Electrical conductivity of the groundwater in the Salento coastal area exceeds 15,000 μS/cm. Reduction in water withdrawal of 17% might be achieved by using treated water from the sewage plants in the coastal area in the irrigation period. The percentage of water supplied for irrigation purposes might be restored during the non-irrigation season (surplus of treated effluent may be 27%)	Agriculture 80%, forestry 13%, artificial surfaces 7%
SLOVENIA: Kobariškistol and Mia – Matajur aquifers	The physical and chemical parameters of surface and groundwater show the characteristics of natural conditions. Possible human impacts practically absent within the test area. All measured parameters (pH, electrical conductivity, oxygen regime, total organic carbon, nutrients, microbiology, and metals) indicate that surface water and groundwater in test areas are not polluted and have a good chemical status. Groundwater hydro-chemical type is Ca – HCO3. Good surface and groundwater quality status in test areas in NW Slovenia (Kobariškistol and Mia – Matajur aquifers)	Artificial areas 0.28%, agricultural areas 14.56%, forest and semi natural areas 85.27%
CROATIA: Northern Istria – springs Gradole, Sv.Ivan and Bulaž	There is an increasing trend of total suspended solids (TSS) in all springs. However, the content of TSS depends primarily on hydrological conditions, so this should not be considered as an indicator of pollution. During 2003–2013 there was a decreasing trend of nitrates (below maximum allowable concentration (MAC)). Microbiological contamination is present and is associated with the hydrological conditions. Higher concentrations of total number of micro-organisms and micro-organisms of faecal origin were occasionally observed, mostly from untreated urban waste waters. For all springs, phosphates and total phosphorus are very low. The values of nearly all indicators are decreasing, and the water quality of springs is improving	Sv. Ivan: pastures 2.61%, coniferous forest 4.07%, land principally occupied by agriculture 5.18%, complex cultivation patterns 6.53%, natural grasslands 7.45%, transitional woodland 9.74%, mixed forest 10.62%, broad-leaved forest 53.31%
CROATIA: Southern Dalmatia – spring Prud and Blatskopolje	Different hydro chemical faces of the two pilot areas in Southern Dalmatia (SD). Sampled waters from island test area (Blatskopolje) range from calcium-hydrogen carbonate to sodium-chloride hydro chemical faces, which indicates strong influence of the sea water intrusions. Waters from continental test area range (Prud) from calcium-hydrogen carbonate to calcium-sulphate hydro chemical faces,	Blatskopolje: agriculture 56.8%, forestry 38.7%, artificial surfaces 4.5%. Prud: forest and semi natural areas 68.88%, agricultural areas 29.14%, artificial surfaces 1.77%, water bodies 0.18%, wetlands 0.04%

(*continued*)

Table 4 | continued

Country/test area	Basic water quality characteristics and trends	Land use
	suggesting recharge from deposits rich in sulphate minerals. Trends of indicators of water quality are negative, showing decrease in the concentration of water quality indicators	
BOSNIA AND HERZEGOVINA: Trebižat River	In Trebižat River, high saturation with oxygen, mostly due to phytobenthos activities and occasionally content of the substances that can be oxidized and decomposed by micro-organisms. Increased concentrations of copper and total chromium, which were above the MAC for surface water (2010–2014). Concentrations of lead in the range of limit values. In Trebižat River absence of fresh pollution indicators in the basin (could be potentially eutrophicated and have impact on biological status)	–
MONTENEGRO: Nikšić	Good quality of water used for water supply in the test area in Niksic. Deviations of quality parameters (turbidity and mild microbiological contamination) from MAC only during heavy precipitation. Only chlorination is applied in springs	Agriculture 28.73%, forestry 65.13%, artificial surfaces 4.94%, water bodies 1.2%
SERBIA: VelikiRzav	VelikiRzav very vulnerable to the impacts of weather. There are areas exposed to erosion, as well as arable land. The conditions of heavy rainfall or rapid snowmelt bring on drastic deterioration in water quality. Sources of water pollution classified into two categories: scattered and concentrated ones. Concentrated pollution is characterized by the point of discharge of wastewater into the recipient, whereas the scattered sources of pollution are generated spatially. The scattered sources of pollution include all surface and groundwater pollutants which originate from: the population not connected to the sewerage, tillage, leaching from forest and soil surfaces, livestock, unregulated municipal landfills and other human activities	–
ALBANIA: Drini basin	Discharging of industry polluted water and untreated municipality sewage water in river Drini i Bardhë has a huge consequence for the water's fauna. A long and uncontrolled discharge of municipal sewage water, agricultural and industrial waste in Drini i Bardhë River inflicted the change in water quality. With the polluted water in the bank of Drini i Bardhë River also the organic and inorganic substances are being discharged. It is possible to reduce or to stop this negative trend. Turbidity exceeds the standards of drinking water. Information provided by the Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI) describes drinking water quality, used by water users, suppliers, etc. Tastes and odours in water may be derived from a variety of conditions and sources (e.g. chlorination)	Agriculture 30.26%, forestry 21.76%
GREECE: Corfu Island	Water quality of the surface water systems of Corfu is good. No heavy pressures identified. The three groundwater systems identified assessed to be in a good chemical quality status. High concentrations of sulphates are due to the natural geological background. Increased values of nitrates and ammonium are due to the diffuse and point pollution sources of human activities. In the coastal areas, some increased values of chlorides due to the sea intrusion because of exploitation and natural causes	Area under cultivation and fallow land 73.0%, forests 10.2%, areas occupied by settlements 4.9%, pastures 4.7%, areas under water 1.1%, other areas 6.1%

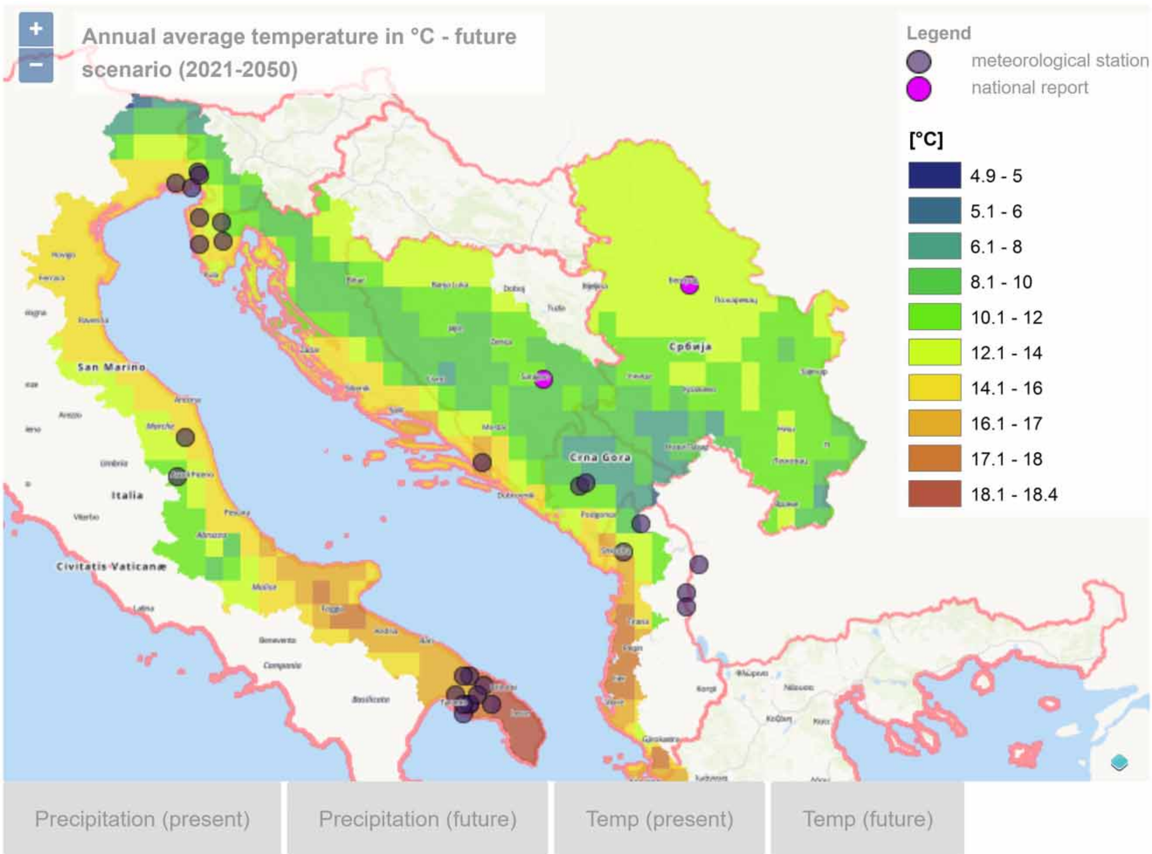

Figure 3 | DRINKADRIA web based platform – Annual average temperature in °C – future scenario (2021–2050).

information system (GIS) platform. One of the most important results is the fact that CBWSS have common characteristics in most of the countries involved in the DRINKADRIA Project (Table 5). In order for the CBWSS to become comparable, they are grouped in three categories: (1) Active WSS – currently operating; (2) Inactive WSS – operating in the past; and (3) Potential WSS – agreements are being signed or WSS in the phase of construction. Four project partners have reported that they have either active or potential CBWSS (Table 6). The main focus was on identifying CBWSS, with regard to the fact that there is not enough information and documentation on a national level, and legislation concerning CB water supply in most countries is usually chaotic and indefinite.

Table 5 | CBWSS reported by project partners per CB system

CBWSS	Active WSS	Inactive WSS	Potential WSS
SLO-IT	4	2	2
SLO-CRO	7	2	5
CRO-BIH	6	0	0
CRO-MNG	1	0	0
ALB-GRC	0	0	1
ALB-ITA	0	0	1

Table 6 | CBWSS reported by project partners per country

CBWSS	Active WSS	Inactive WSS	Potential WSS
Serbia	3	0	5
Albania	1	0	1
Italy (FB1)	1	0	0
Italy (FB2)	5	0	0

Standard protocols and procedures for efficient and effective CB water supply and regional drinking water supply economics model

DRINKADRIA focuses on the implementation of reports, addressed in the framework of CBWSS, including guidelines for technical assessment, legal framework for WSS development and performance, economic assessment, operational and service standards (quality, quantity, dynamics, pressure, temperature) and finally risk management instructions. Special focus is given to the specific features of the Adriatic sub-region regarding parameters such as asset management, active leakage control, water quality and salt water intrusion problems and WSS management, in cases of extreme potential droughts. Special focus is also given to water supply economics (financial management of water utilities expenses and incomes) and water pricing policies. At a national level, water pricing policies have always been a challenging topic, with increased focus on the case of a bilateral CB level. Long-term WSS assets are the key element for an effective and successful long-term planning. Within this framework, during DRINKADRIA implementation an appropriate methodology has been developed, to reach comparable results regarding the pricing policies applied by the water utilities involved from each country (DRINKADRIA 2016b). The integration of an effective methodology based on the calculation of the mean net cost and the mean payable amount led to comparable results concerning existing pricing policies for several levels of monthly water consumption (e.g. using a 5 m^3 water consumption step) (Kanakoudis *et al.* 2014). This methodology is accompanied by the categorization of the water utilities into groups, regarding their size (population served) and location (mainland, coastal or island). Taking into consideration the fact that at EU level all member states are obliged to develop effective pricing policies and full water cost recovering (direct, environmental and natural resource cost), the integration of this methodology within DRINKADRIA activities could lead to more countries establishing more effective pricing policies. There are certain aspects (e.g. water flow, water quality, water supply volume, emergency supply, measurement, event of force majeure, etc.) that are considered for transparent bulk (CB) water supply agreement negotiations. These aspects are considered in order to assure a fair (price) agreement and above all a sustainable CB drinking water supply. The existing CB drinking water supply agreements within the Adriatic region are based on simple and short contracts, where the price of CB water supply (CBWS) is defined by public water utility users (the price for cubic meter of CB water supply equals the price of household consumer's charges). In order to ensure a socially fair price for drinking water in CBWS, full economic cost should be considered, with emphasis on efficient cost allocation. In conclusion, the integration of a separate accounting approach in order to allocate costs (proportionally) of public water supply and costs of CBWS requires immediate actions.

Pilot actions in the Adriatic area

Nine pilot actions have been developed during DRINKADRIA's implementation, with special focus on water quality (including sea water intrusion) or water quantity (water losses reduction). Ageing water supply infrastructure and the level of water losses in a WSS exceeding 40% of the System's Input Volume are currently two of the most challenging issues that Adriatic counties are called to face. Through the implementation of DRINKADRIA pilot actions, relevant measures for more efficient and effective water supply management in terms of reduced water losses and improved water quality are prioritized. Reduction of water losses significantly contributes to economic and environmental efficiency.

Rehabilitation of WSS includes high costs, while on the other hand the development of improved monitoring and modelling is more cost effective and provides information necessary for short-term preventing actions such as: (i) identification of distribution network zones characterized by higher water losses rates; (ii) localized information on leakage; (iii) effective pressure management; (iv) development of district metering areas; and (v) identification of water quality and quantity characteristics. Furthermore, these pilot actions provide a training tool for water utilities representatives, experts and technicians. The results indicate that two-thirds of the pilot cases are focused on leakages and monitoring of flow rates in the distribution systems, while only one-third are focused on water quantity and quality and on the seawater intrusion into the coastal groundwater aquifer, which is a common problem across the Adriatic region. Investments and supply of equipment are implemented in several pilot actions (Table 7). The methodology used for the monitoring for each kind of pilot action consists of the continuous measurement of different parameters to investigate how the measures taken will affect the values of these parameters. This methodology is described below (Table 8). This kind of collected data led to an improvement of WRM, especially groundwater, with regard to quantity and quality, as well as WSS, through individual improvements and integration of good practices (DRINKADRIA 2015b).

CONCLUSIONS

The present paper presents the path to policy recommendation towards CB drinking water supply in the Adriatic region WRM through the networking and cooperation of several stakeholders, which are called to face similar challenges. Within the DRINKADRIA project networking, the following issues are discussed: (a) the development of an overview and evaluation of CC characteristics and water resources availability in the Adriatic sub-region, taking also into consideration CC impacts on water resources; (b) the development of a set of data of water quality analysis and trends and the vulnerability assessment of water resources; (c) the collection and critical evaluation of the historical development of CB drinking WSS; (d) the establishment of a database concerning standard protocols and procedures for efficient and effective CB water supply and regional drinking water supply economics model; (e) the implementation of a web-based GIS shared platform; and (f) the implementation of the methodologies, tools and techniques in the standardized pilot actions. The DRINKADRIA project resulted in the thorough analysis of CB water resources in the

Table 7 | Summary of pilot actions by project partners

Institution	City, country	Pilot case	Pilot action
CATO	Trieste, Italy	San Dorligo Della Valle	Water losses: district metered areas (DMAs) formation; leakage management; hydraulic simulation model development
Veritas	Venezia, Italy	Murano island	Water losses: leakage detection
		Mogliano	Water quality: efficiency analysis of pollutant decontamination treatment methods
		Venezia	Water quality: evaluation of microbiological detection technique
ATO3 Marche	Macerata, Italy	Marche	Water losses: installation of metering systems; real-time monitoring tools
CNR	Bari, Italy	Ostuni	Exploitation of sustainability of groundwater exploitation; seawater intrusion
Water Utility Nova Gorica	Nova Gorica, Slovenia	Nova Gorica drinking water supply network	Water losses: metering systems and monitoring; hydraulic simulation model developed
Water Utility Istria	Buzet, Croatia	Buzet drinking water supply network	Water losses: metering systems
Water Utility Neum and Hydro Engineering	Neum and Sarajevo, Bosnia and Herzegovina	Neum water supply network	Water losses: leak measurements; reconstruction activities; final measurements testing IWA method
Public Utility Niksic	Niksic, Montenegro	Niksic drinking water supply network	Water losses: GIS and supervisory control and data acquisition (SCADA) update; hydraulic model developed; DMAs formation; flow and pressure meters establishment
Water Utility Corfu	Corfu, Greece	Corfu city drinking water supply network	Water losses: update of hydraulic simulation model; NRW reduction

Table 8 | Applied methodology for the monitoring of pilot actions – parameters monitored during the pilot actions' implementation

Pilot action	Category	Parameters
Water losses	Financial performance indicators	Non-revenue water as percentage by volume; Non-revenue water as percentage by cost; Annual cost of apparent losses; Annual cost of real losses
	Technical performance indicators	Apparent losses per service connection per day; Real losses per service connection per day; Real losses per length of main per day; Real losses per service connection per day; Unavoidable annual real losses (UARL); Infrastructure leakage index (ILI – real losses/UARL)
	Numerical model	Identification of the trend of pressure, the flow rate values, and the flow direction; Upload of previously recorded data and simulation of the network behaviour in that period/situation; Execution of water balances of the consumption in the district analysed putting in evidence mean, maximum and minimum values to better evaluate the water losses of the district; Execution of a quantification of continuous industrial water consumption; possibility of viewing data as stored or complete; Possibility of viewing the water volumetric balance once the desired periods set
Quality	–	Mercury and iron concentration in groundwater wells; metal abatement percentage; faecal contamination indicators, pathogenic micro-organisms: selectivity; sensitivity; quantification; detection time
Quantity	–	Natural flow rate; groundwater level and seasonal variation; rainfall amount; chemical-physical parameters: temperature; alkalinity; conductivity; nitrates
Seawater intrusion	–	Microbiological parameters: faecal indicators; pathogenic micro-organisms; chemical-physical parameters: dissolved organic carbon; pH; temperature; conductivity; water depth in wells

Adriatic region, taking into consideration CC impacts. The results showed that there are some water resources more vulnerable than others, indicating that adaptive measures need to be taken. The analysis showed that CC will impact negatively on water resources availability, resulting in decreased water availability, while increased water demand will stress water resources even more. Different water quality problems are faced in the region, such as pollution due to human activities (increased nitrates values, BOD values, etc.) and salt water intrusion. Water resources safety was also assessed. The results showed that each country faces water safety in a different way. When it comes to drinking water, the implementation of HACCP plans or WSP is obligatory in some countries, while in others it is not. Water resources vulnerability assessment indicated that high complexity exists in some cases.

The general guidelines are set for pricing models to be used in the case of CB water resources used for drinking water supply. The guidelines for a bilateral contract in the case of CB water supply are also set. Legislation and standards used in different countries are gathered and analysed. Nine pilot actions are elaborated to improve water resources efficiency in terms of both quantity and quality. The reduction of Non-Revenue Water is recognized as the most important issue that should be tackled, especially in countries having the characteristics of the ones located in the Adriatic sub-region with regard to water scarcity conditions and high fluctuations in precipitation. The results obtained from the pilot actions showed that the function of WSS, especially leakage reduction, has been improved, and so has the quality of the supplied drinkable water. Also, a method for sea-water intrusion limitation has been developed.

The effective cooperation of stakeholders and experts from different categories with upper-level technical and scientific skills and capabilities is the first critical success factor of the DRINKADRIA project. Research organizations provide a state-of-the-art knowledge, water utilities contribute with their unique many years' experience in water supply and recourses management, and regional authorities contribute to the capitalization of the project's results and to policy recommendation. Eight countries located in the Adriatic region (Italy, Slovenia, Croatia, Serbia, Albania, Bosnia and Herzegovina, Montenegro and Greece) are called to face similar problems, having the same strategic goals and objectives. This fact constitutes the second critical success factor, while the third one is the development and the integration of a common language and the adoption of effective methodologies, tools and techniques. The ultimate goal is to utilize country borders as an opportunity to eventually establish an institutionalized mechanism of 'growing up together'.

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