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Does a change of irrigation technique impact on groundwater resources? A case study in Northeastern Italy

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ABSTRACT

The Venetian plain is a densely populated area and one of the most economically competitive regions in Europe. Therefore, a sustainable management of the water resources has to be accomplished to preserve both the social and economic value of this area and the regional environment in accordance with the European water policy directives. This paper presents the analysis of hydrologic and hydrogeological water balances of the high alluvial plain (approximately 790 km^2) highlighting some important peculiarities that could be crucial for the local water policy. By focusing on the importance of different water budget components, the obtained results indicate in the irrigation the most relevant component of the aquifer recharge. Thus, the irrigation management policy of the Land Reclamation Consortia strongly influences aquifer recharge. Moreover, future scenarios (2071–2100) for the high Venetian plain are performed taking into account the changes of climate and irrigation policy. The inflow of the aquifer suffers a decrease ranging from 18% in the scenario influenced by climate change to 28% in the scenario affected by both the variations. In particular, the irrigation recharge shows the highest reduction due to both an increase in evaporation, owing to an increase in the surface temperature, or the irrigation methods. Therefore, the irrigation management policy adopted by the Land Reclamation Consortia is a fundamental concern. Changes from surface irrigation to spray or drip irrigation could strongly affect the aquifer recharge. The classical technique of surface irrigation is very useful in terms of aquifer recharge in comparison with drip or spray irrigation. However, it also requires a huge volume of water compared with the minimum desirable streamflow of a river and its management policy. Currently in Italy, the transition from conventional irrigation systems to water saving techniques is favored by the Land Reclamation Consortia in response to European and Italian directives. However, the possible reduction of the aquifer recharge could influence the actual social and economic condition of the Venetian plain because the human and industrial water needs are mostly dependent by groundwater exploitation. Therefore, water saving activities should be accompanied by appropriate corrective actions to reduce the environmental and social impact due to the decrease in aquifer recharge.

1. Introduction

The 71% of the earth surface is covered by water, but its volume is only 0.13% of the total earth volume. The 3% of water is represented by fresh water, but only 0.26% is available. The most part of the fresh water is stored in glaciers and ice caps (69%), while 30% is hosted in aquifers as groundwater. The residual 1% of fresh water is superficial of which 21% into the lakes (Shiklomanov, 1993). Therefore, the quantification of available groundwater for human purposes, its protection, as well as the protection of groundwater dependent ecosystems, and its sustainable management are crucial issues for both scientists and policy communities at regional and local scales. The 75% of European citizens use groundwater for their water supply (European Commission, 2008). Italy, together with Spain, Cyprus and Malta, is one of the countries with higher water stress due to consumptive uses like irrigation (European Environment Agency, 2016). The scarcity of water, as well as the water quality problems, would require an improvement

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of the water management in these countries aimed to a sustainable exploitation of groundwater (Ziolkowska and Ziolkowski, 2016). Multilayered aquifer systems, especially those composed of gravel or sandy gravel strata, present the most suitable conditions for groundwater exploitation. Confined aquifers constituting these systems are usually characterized by both low vulnerability and high quality of the water resource (Hayashi et al., 2009; Konikow and Kendy, 2005; Somaratne and Hallas, 2015). In this context, the hydrogeological characterization of both the recharge area of the system and the components of its water balance is crucial for integrated and sustainable groundwater resource management (Birkle et al., 1998; Claessens et al., 2006; Devlin and Sophocleous, 2005; Kendy et al., 2004; Kløve et al., 2011; Manghi et al., 2009; Narasimhan, 2008; Scanlon et al., 2012; Sophocleous, 2010, 2012; Zhou, 2009).

A water balance (or water budget) is an accounting of all water volumes that enter and leave a three-dimensional space over a specified period. In general, the movement of water (i.e., hydrologic cycle) can be approached both at regional and local scales. From a global point of view, water evaporates from the seas with variable rates and it moves through the atmosphere as clouds. Subsequently, it can precipitate directly in the seas or into land as rain or snow remaining in the hydrologic cycle for very different time. As a matter of fact, water fell as snow may be stored as snow or ice for very longtime, while water fell as rain may be drained to streams returning to the sea in a relatively short time. Otherwise, the rain may seep into the ground by infiltration. The water is stored in the voids of the soil porosity constituting an upper unsaturated part and a lower saturated one (aquifer). The movement of water into aquifer is essentially horizontal with a lower velocity than the river, thus its return to the sea will be more delayed. The global qualitative concept of the hydrological cycle can be exported to a limited area and on a defined time interval with the aim of evaluating the exchange of water volumes among the different part of the hydrosphere (i.e., water balance). Different approaches can be used to establish the water balance of a region. They range from simple analytical water balances (Sene, 1998; Narasimhan, 2008; Mollema et al., 2013) to more complex two-dimensional or three-dimensional numerical models (Rayburg and Thoms, 2009; Tóth et al., 2016; Wen et al., 2013). In addition they can be applied from the local scale of an island (Praveena et al., 2012; Megalovasilis, 2014) to the regional scale of plains or rivers basins (Claessens et al., 2006; Thompson et al., 2009; Cao et al., 2013), as well as at a global scales (Döll et al., 2014). The central plain of the Veneto Region in Northeastern Italy (Fig. 1) is a typical example of a highly exploited multilayered confined aquifer without an established water balance. A local water balance was conducted in the western part of the plain towards Vicenza (Sottani et al., 1982), while a regional hydrogeological balance is available for the plain of Friuli Venezia Giulia toward East (Zini et al., 2013). Moreover, the Veneto plain is currently one of the most extensively inhabited and economically competitive regions in Europe (Sofia et al., 2014), and its economic growth in recent decades has increased the demand for surface water and groundwater for agricultural, industrial and human purposes. The Venetian plain is characterized by two main hydrogeological units of alluvial origin: a large, unconfined aquifer that extends southward from the Prealps in the upper part of the plain (high plain), and a multilayered confined or semi-confined aquifer system in the lower-lying part of the plain toward the Adriatic Sea (middle and low plain; Carraro et al., 2013, 2015; Piccinini et al., 2016). The water needs of the three main cities in the eastern part of Veneto Region (i.e., Padua, Treviso and Venice; Fig. 1) are almost completely met by the multilayered aquifer system in the middle plain. For instance, the Venice municipality has a fluctuant population of 2,740,000 inhabitants and approximately 120,000 tourists. Approximately 87% of the public water supply for human activities in the area is guaranteed by groundwater, and only a

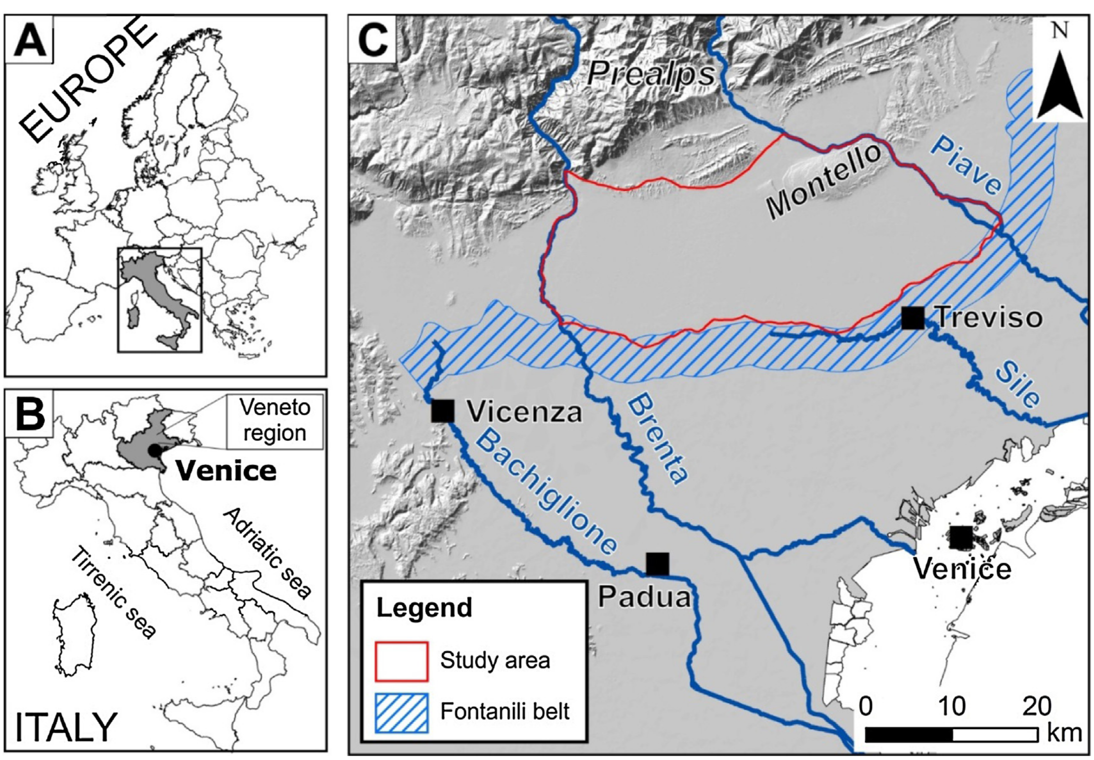

Fig. 1. Veneto Region and study area delimited by the red line. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)