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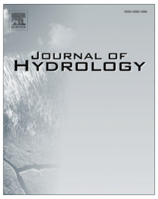

Assessment of climate change impacts on soil water balance and aquifer recharge in a semiarid region in south east Spain

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SUMMARY

Climate change forecasts in a semiarid region are of much interest to academics, managers and governments. A significant decrease in annual precipitation and an increase in mean annual air temperature are expected; consequently, changes in the soil water balance and groundwater recharge to aquifers are expected as a response to climate change forecasts. In this context, our study aimed to assess the impact of climate changes on the soil water balance and natural groundwater recharge in a semiarid area (Ventós-Castellar aquifer, SE, Spain). To this end, we selected Global Climate Model HadCM3 after comparing it with two other models (ECHAM4 and CGCM2). The HadCM3 model climate data (air temperature and precipitation in two emission scenarios: A2-high and B2-low; 2011–2099) were coupled to a HYDROBAL hydrological model to determine the soil water balance. The HYDROBAL model results showed that climate change will have a significant impact on the soil water balance in the study area, especially on groundwater recharge during the latter period. In both the A2-high and B2-low scenarios, the selected years to run the HYDROBAL model showed a decrease in water balance components (precipitation, actual evapotranspiration, aquifer recharge and runoff) in relation to the baseline period (1961–1990). Over the projected period (2011–2099), we expect fewer rainfall events (>15 mm), which promote aquifer recharge, longer dry summer seasons and, consequently, reduced average annual recharge that ranged from 3% to 17%; 10–49 mm, if compared to the baseline period. The methodology developed in the present study can be beneficial for assessing the impact of predicted climate change on groundwater recharge, and can help managers and planners to devise strategies for the efficient use and conservation of freshwater resources.

1. Introduction

Global climate change will have a strong impact on the hydrological cycle and, therefore, on water resources in many regions of the world, which is the general agreement reached by academics and governments (Kundzewick and Somlyódy, 1997; Allen and Ingram, 2002; Huntington, 2006; Wilby et al., 2006; IPCC, 2007, 2013). Groundwater is an essential component of the hydrological cycle that could be seriously affected. Variability in annual precipitation is expected to have direct consequences on groundwater resources (Jyrkama and Sykesa, 2007; Dragoni and Sukhija, 2008; Kundzewicz and Döll, 2009; Green et al., 2011). However, it is hard to establish global potential effects because the relation between climate compounds and groundwater is a rather complex one. For this reason, advancing further in our understanding of the impact of climate change is necessary because, on a global scale, one third of the world population depends on groundwater, especially in semiarid areas. Therefore, groundwater resources may be relatively robust in response to changes in driving climate variables under climate change if compared with surface water given the buffering effect of groundwater storage. Hence the role of groundwater in water resources management is particularly beneficial because it can be used to support public water supply projects and to study ecosystem services during the drought periods expected in future climate change scenarios. Groundwater resources will depend on changes in the volume and distribution (spatial and temporal) of natural recharge.

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The latest Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC, 2007, 2013) state that the mean air temperature on the global surface has increased by 0.6 ± 0.2 °C since 1861, and predicts an increase of 2–4 °C in the next 100 years. More frequent intense and extreme weather events (including drought and flooding) are also expected. Based on the IPCC (2007, 2013) predictions, annual air temperatures will show a warming rate of between 0.1 and 0.4 °C per decade, but this impact could be particularly severe in south European countries like Spain (Giorgi et al., 2004; Alcamo et al., 2007). The warming pattern shows a strong south-to-north gradient, especially in summer, which indicates a warming rate across southern regions of between 0.2 and 0.6 °C per decade. For annual precipitation, trends in Europe for the 1900–2000 period have shown a contrasting picture between northern Europe (10–40% wetter) and southern Europe (up to 20% drier). In most European countries, these changes are more marked in winter. Annual precipitation predictions in northern Europe indicate an increase from 1% to 2% per decade, with a decrease of up to 1% per decade (and even up to 5% in summer) in southern Europe. The frequency and duration of very wet periods have significantly decreased in many regions in recent decades (Hiscock et al., 2012). These general simulations have been specified for Spain, where an increase in the mean annual temperature of 2.5 °C and a decrease in annual rainfall ranging from 2% in northern basins to 17% in southern basins are expected. These predictions of climate change in south Europe, particularly in SE Spain, will have a considerable impact on agriculture and water resources, especially on the natural groundwater recharge of aquifers (Ayala-Carcedo and Iglesias, 2000; CEDEX, 2012).

Quantifying the impact of climate change on groundwater resources requires both reliable climate change forecasting and accurate groundwater recharge estimations (Maxwell and Kollet, 2008). Hydrological models can be combined with climate scenarios generated from downscaling Global Climate Models (GCMs) to produce potential scenarios of climate change effects on groundwater resources on the local scale. The IPCC gives a set of GCMs (e.g., HadCM3 from the UK, ECHAM 4 from Germany, and CGCM2 from Canada) with a well standardised group of scenarios (e.g., A1B, A2, B1, B2, etc.) for climate impact studies.

In the last decade, a growing number of case studies has been generated in an attempt to quantify the likely direct impacts on groundwater (Scanlon et al., 2006; Hendricks Franssen, 2009; Green et al., 2011; Herrera-Pantoja and Hiscock, 2008; Viviroli et al., 2011; Stoll et al., 2011; Thampi and Raneesh, 2012; Ali et al., 2012). Thus many of these studies have predicted decrease in recharge values over the 21st century. However, other studies predict an increase in aquifer recharge under certain conditions and periods (Döll, 2009; Gurdak and Roe, 2010). Mediterranean region shows a high vulnerability to changes on meteorological variables such as temperature or precipitation. Otherwise, projections indicate an increased likelihood of droughts (Iglesias et al., 2007). Many climate change studies have consistently predicted a reduction in groundwater recharge (Manzano et al., 1998; Younger et al., 2002; Bates et al., 2008; Döll, 2009; Aguilera and Murillo, 2009; Guardiola-Albert and Jackson, 2011; Hiscock et al., 2012; Pulido-Velazquez et al., 2014). However, more studies about these changes are needed, especially in arid and semiarid Mediterranean area, where water resource availability is very reduced.

Therefore, we carried out this study to assess the impact of climate change on the soil water balance and natural groundwater recharge in a small aquifer in a semiarid area (SE, Spain). This well known karstic aquifer can be considered as well representative of the kind of aquifers in this region. Temperature and precipitation data from a selected GCM, previously downscaled by AEMet (2009), were coupled to the HYDROBAL hydrological model, which has been previously tested in this semiarid area with good results (Bellot and Chirino, 2013; Touhami et al., 2013, 2014). Impact on groundwater recharge was assessed for two emission IPCC scenarios: A2-high and B2-low. This work attempts to make up for the lack of such studies in semiarid ecosystems.

2. Study area

The study area (Fig. 1) is a small aquifer called Ventós-Castellar located in the Municipality of Agost in the province of Alicante in SE Spain (38° 28′N, 0° 37′W). Altitude ranges from 300 to 840 m a.s.l. Slopes vary between 25% and 30% and are mainly south-facing. The Ventós-Castellar aquifer consists chiefly of

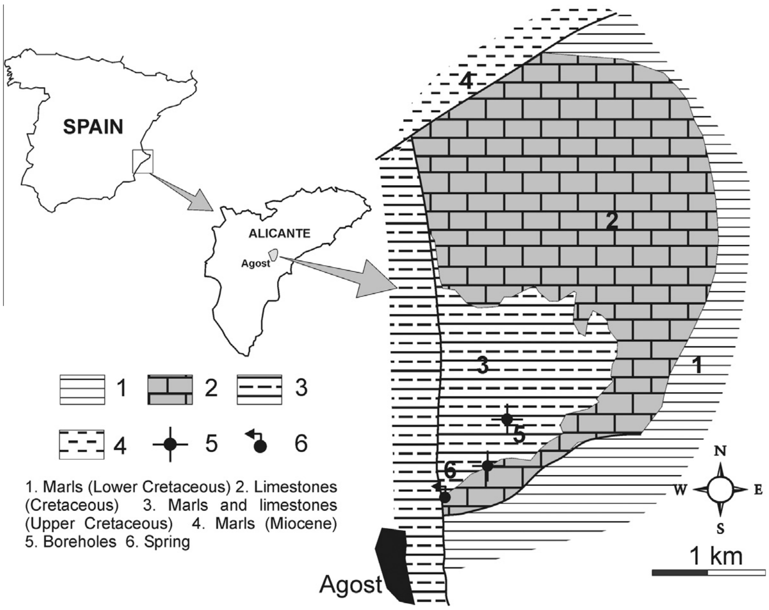

Fig. 1. Geographical location and geological setting of the Ventós-Castellar aquifer.