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Projected impacts of climate change on water availability indicators in a semi-arid region of central Mexico

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ABSTRACT

In many arid and semi-arid regions of the world, the scarcity of water resources, increasing population and the experience of recent droughts are exerting great pressures on water resources. Climate change is anticipated to exacerbate the vulnerability of water resources, which clearly highlights the need for developing sustainable water management policies and appropriate adaptation strategies.

In this paper, the likely impact of climate change on water availability indicators in a semiarid region is explored through a case study in a developing country. Queretaro River Basin (QRB) in Central Mexico, is presented as an example of a semi-arid region that is facing growing pressures on the availability of water resources to sustainably meet social, economic and ecological needs. The output of seven downscaled Global Coupled Ocean-Atmosphere General Circulation Models (AOGCMs) for the B1 and A1B greenhouse gas emissions scenarios (GHGES) were used to investigate the likely impacts of climate change on water resources in the QRB. The computed future scenarios of climate change predict that increases in mean annual temperature ranging from 0.8 °C to 4.8 °C and decreases in mean annual precipitation ranging from 17% to 22% could result in a decline of up to 9.16% in the available water for groundwater recharge and runoff by the end of the 21st century. Results also suggest that for the future, both dry and wet events will become more severe and frequent, increasing the vulnerability of water resources and compromising sustainability. Therefore, it is advisable that water management planning considers flexible adaptation strategies in order to allow for adjustment under different scenarios of water availability, if the implementation of unbiased, efficient and economical water resources strategies is to enhance sustainability and resilience to climate change in the long-term.

1. Introduction

The warming of the Earth's climate is affecting social, ecological and economic systems around the world (Patz et al., 2005; IPCC, 2007; Howat et al., 2007; Hein et al., 2009; Dai, 2010; van der Velde et al., 2012; Smith and Katz, 2013). Due to the relationship between the climate system and the hydrological cycle, the impacts of climate change on water resources is one of the most important challenges facing our planet in the 21st century (Mearns and Norton, 2010; UN, 2011); especially in many arid and semi-arid regions of the world, where the scarcity of water resources, increasing population and the experience of recent droughts have led to famine, loss of livestock, crop failure, migrations and death (Mishra and Singh, 2010; Shi et al., 2011; Kharraz et al., 2012). Water scarcity can be defined as an excess of water demand over available supply (FAO, 2012), and is characterized by unsatisfied demand, tensions between users, competition for water, over-exploitation of groundwater resources and vulnerability of natural resources (Vairavamoorthy et al., 2008; Kharraz et al., 2012; Acharyya, 2014; Selby and Hoffmann, 2014). According to IPCC (2007), vulnerability is the degree to which a system is unable to cope with the adverse effects of climate change, and in many arid and semiarid areas in developing countries, people and ecosystems are particularly vulnerable to climate change given that decreasing precipitation and increasing temperature make drought events a recurrent phenomenon (Kiem and Austin, 2013). During the last decades Africa, the Middle East, South Asia, Northern China, Mexico, North East Brazil and the western coast of South America, have experienced severe droughts with important impacts on their economy, ecosystem health, agriculture, energy production and water quantity and quality (Zhang, 2003; Mendoza, 2005; Kusangaya et al., 2014; Selby and Hoffmann, 2014).

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The scarcity of water resources and the effects of other extreme events such as droughts, flooding, storms, sea-level rises and heat waves introduce a water resources management challenge for these regions, since the effects of global warming are projected to exacerbate the vulnerability of water resources undermining economic development (Ragab and Prudhomme, 2002; Chiew et al., 2003; Kusangaya et al., 2014; Vargas-Amelin and Pindado, 2014). For example, in sub-Saharan Africa, increasing droughts are likely to diminish the maize cropping area by around 40% of current farmland, whereas in other areas of the region, rising temperatures will damage the grassland ecosystems used to graze livestock (World Bank, 2013).

Consequently, unless governments apply adequate water policies, which take into account the impact of climate change, water resources management could face serious problems (Hanak and Lund, 2012). In order to prepare for future challenges, decision makers need methodologies which take into account scenarios of climate change at regional level to envisage likely effects on water resources. The assessment of the likely impacts of climate change on water resources is of great importance in order to understand how different sectors could be affected; and furthermore to develop sustainable water management policies and appropriate adaptation strategies that allow for the successful administration of water demand variability, conflicts over water resources allocation, and producing emergency schemes in drought and flood situations.

In this study, the likely impact of climate change on water availability indicators in a semiarid region is explored through a case study in a developing country. The study focuses on the Queretaro River Basin (QRB), a semi-arid region of Central Mexico, which is facing a growing crisis in water availability to meet social, economic and ecological sustainability. In this region, as in other arid and semi-arid regions of the world, the scarcity of surface water resources has led to over-exploitation of groundwater resources (Shi et al., 2011) and by doing so puts any future development at risk. The output of seven downscaled Global Coupled Ocean–Atmosphere General Circulation Models (AOGCMs): BCCR, CSIRO, GISS, INM, MIROCh, MIROCm and NCAR, for the B1 and A1B GHGES, and a daily water balance are used to produce future scenarios of water availability. An assessment of extreme hydrological periods is carried out using the Decile Index and a discussion of the impact of future climate on water availability and water management is presented.

2. Study area

Queretaro is a state in central Mexico between the northern parallels 20°01′ and 21°40′ and the western meridians 99°03′ and 100°36′. The QRB is located in the western area of Queretaro State. It encompasses the metropolitan area located in the municipalities of Queretaro, Corregidora, El Marques and Huimilpan (Fig. 1). Surface water resources are limited in this basin. The most important surface runoff is the Queretaro River, which only carries water during the rainy season when surface water is stored behind small dams and levees. The surface water storage capacity is about 6 Mm^3 and is used to irrigate 780 ha of agricultural land and also to provide flood control. Given this situation, groundwater resources have been the main source of water during the last few decades. Consequently, groundwater resources in the basin during the last 30 years have been dramatically over-exploited. Water tables dropped from −20 m below ground level in 1980 to −140 m in 2010. A groundwater recharge annual deficit of approximately 76 Mm^3 in the Queretaro Valley aquifer has produced a decrease in groundwater levels of between 2 and 6.6 m annually, with a consequent increase in pumping costs (CEA, 2009).

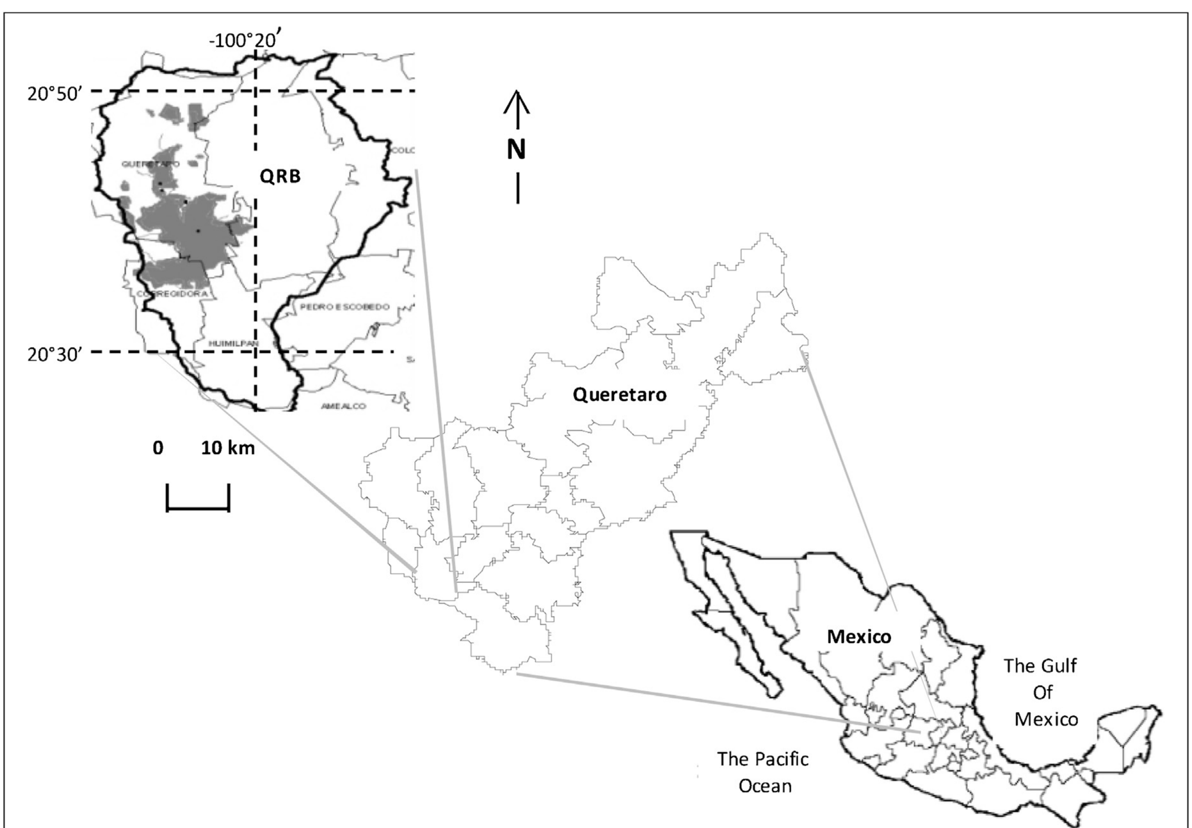

Fig. 1. Location of Queretaro River Basin, Mexico.