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Assessment of the nexus between groundwater extraction and greenhouse gas emissions employing aquifer modelling

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Abstract

One of the main sources of Greenhouse Gas Emissions (GHG) is electricity consumption which is getting used for different purposes..Water pumping, especially, pumping from deep groundwater resources consumes a lot of energy. In arid and semi-arid areas, in which groundwater is the only source of water, water pumping is done for different purposes such as agricultural, industrial and urban uses. Kerman plain is one of these arid and semi-arid areas which is located in South East of Iran. Groundwater reliance and aquifer decline are the most prominent challenges that this area is faced with in recent years. This challenges increase the demand for more electricity consumption to pump water from the aquifer so that CO_2 emissions will be increased. A large percentage of water extraction from the aquifer is used for agricultural purposes. In this paper, by modelling Kerman plain aquifer with MODFLOW software by using Geographical Information System (GIS) database and also studying height of groundwater table from 1999 to 2012, electricity energy consumption of groundwater extraction for agricultural, industrial and urban water supply is calculated and the CO_2 emissions trends resulted from electricity energy consumption is evaluated. Then model results are examined for a business as usual (BAU) scenario of changes in water resources. As a result the amount of CO_2 emitted from groundwater abstraction by three mentioned sectors is calculated for specified time horizon. Finally, some suggestions are presented for reducing greenhouse gas emissions for the time horizon.

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Keywords: Greenhouse gas emissions (GHG), Electricity Energy, Groundwater, Water pumping, MODFLOW, GIS

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1. Introduction

During the last decade, an unprecedented state of global warming has been witnessed. Many of scientists have argued that increasing levels of carbon dioxide (CO2) emissions as a greenhouse gas, significantly contribute to the warming of global temperatures and climatic instability (IPCC [1]). During recent decades, development in industrial, agricultural and domestic water consumption has intensified the pressure on the water resources in order to satisfy the water demands. Water availability for the above mentioned purposes has become increasingly important topic of international and interdisciplinary research in response to major water challenges which are the main concerns in certain parts of the world. Water supplies for different activities generally require high energy consumption and have contributed to increase in energy use in many parts of the world (Curlee et al. 2008 [2], Goldestein et al. 2002 [3]). A systematic review of energy used in the water industry is often considered within life-cycle assessments (LCAs) (Sabrina et al. 2011 nature climate change [4]). Also a review of LCAs of water industry found that energy use carries the highest environmental burden (e.g. GHG emissions) in most cases consumed as electricity for pumping (Friedrich et al. 2007 [5]).

Growing populations are creating a higher water demand, and in areas where water is already scarce accelerated research will be required to help develop sustainable mitigation and adaptation scenarios to climate change will still be meeting demand (Blickenstaff et al. 2013 [6]). In the areas which groundwater is considered as the only source of water supply, pumping water from regional aquifers is an energy consuming process especially when the aquifer has a declining trend because of overexploitation. In these areas electricity consumption intensifies the production of large amounts of greenhouse gases. In order to manage groundwater resources it's essential to provide aquifer models by which water management options can be applied.

In order to study the impact of multiple activities carried out simultaneously, there is a need to develop a model which can quantify the response of the groundwater system to changes in surface water management options (irrigation and/or agriculture) and groundwater so that proper measures could be adopted for the sustainable management of groundwater resources (Asaf Sarwar and Helmut Eggers, 2006 [7]).

Groundwater flow models are appropriate tools to assess the effect of foreseen future human activities on groundwater dynamics (Moa et al 2005 [8]; Dawoud et al. 2005 [9]; Mylopoulos et al. 2007 [10]). MODFLOW is one of the most common software for groundwater modelling. When applying MODFLOW it represents a step ahead in recognizing the groundwater behavior since knowing the variation of groundwater depth in time and space is important to support decision making on water management (Xu Xu et al. 2011 [11]). Coupling of MODFLOW with Geographic Information System (GIS) is very helpful to assess the impacts of water abstractions from aquifer by assessing the groundwater table trend.

In this paper Kerman plain aquifer is modelled by an integrated coupling of the MODFLOW with GIS. Then the trend of groundwater table and the unit hydrograph is plotted based on 1999 to 2012 data and the groundwater table is plotted with consideration of the current management policy for 20 years later. Finally, according to the plain water balance information and abstractions, electricity energy used for groundwater abstraction is calculated and the GHG emissions resulted from the electricity energy in this plain is calculated for the above mentioned period.

2. Methodology

The modular-finite difference groundwater flow model MODFLOW-2000 (Harbaugh et al. 2000 [12]) was selected to simulate the behaviour of groundwater flow in the study area because it is well-