Geophysical Research Abstracts,
Vol. 11, EGU2009-2542-1, 2009
EGU General Assembly 2009

Simulating the impact of future land-use change on the groundwater system, a case study in Belgium

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Groundwater is a major source of drinking water across the world and plays a vital role in maintaining the ecological value of many areas. However, in many places the quantity and quality of groundwater is jeopardized due to increasing human activity. Assessing the impact of human-induced factors influencing the groundwater system and predicting the magnitude of change in the future is therefore a major scientific challenge. The objective of this paper is to assess the impact of land-use changes, from 2000 until 2020, on the hydrological balance and in particular on groundwater quantity, as results from a case study in the Kleine Nete basin, Belgium. Four future land-use scenarios (A1, A2, B1 and B2) based on the Special Report on Emission Scenarios (SRES) indicate the area of land-use change in the studied basin. The novelty of this study is the successful coupling of a land-use change allocation model (CLUE-S) with a groundwater flow model as alternative to relying on expert judgment for the spatial distribution of the land-use changes in the basin. The CLUE-S model dynamically allocates land-use changes based on a combination of empirical and spatial analyses. Water balance components, groundwater level and baseflow are simulated using the distributed WetSpass model in conjunction with a steady-state MODFLOW groundwater flow model. The applied methodology allows an improved estimation of the range and spatial distribution of the effects of future land-use change on the groundwater system. Results show that the average recharge decreases with 2.9, 1.6, 1.8 and 0.8% for scenario A1, A2, B1 and B2, respectively, over the 20 covered years. The predicted reduction in recharge results in a small decrease of the average groundwater level in the basin, ranging from 2.5 cm for scenario A1 to 0.9 cm for scenario B2, and a reduction of the baseflow with maximum 2.3% and minimum 0.7% for scenario A1 and B2, respectively. Although these averages appear to indicate small changes in the groundwater system, spatial analysis shows that changes in recharge and groundwater level are concentrated within the vicinity of urban centers. Future urbanization as well as areas with a groundwater level decline of more than 5 cm, for all scenarios, are mainly situated within 3 km from current urban centers. The local maximum simulated groundwater level decrease is 45 cm for scenario A1. Hence, spatial planning should take better account of effects of land-use change on the groundwater system and define mitigating actions for reducing the negative impacts of land-use change.