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Preface

"Groundwater recharge: processes and quantification"

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Appropriate quantification of groundwater recharge is required for robust model predictions as groundwater recharge is one of the main drivers of the hydrological system. Direct measurement of recharge is, unfortunately, not possible. Each hydrological sub-discipline came up with their own practical solution to quantify groundwater recharge. In groundwater modeling, it is common to approximate recharge as a fraction of rainfall. In the hydrological component of large climate models, as well as in many surface water models, recharge is viewed as a simple loss term. Vadose zone hydrologists try to simulate groundwater recharge as it passes through the unsaturated zone; they apply a variety of approximate conditions at the soil surface and often simplify the vadose zone as homogeneous. Ecohydrologists are the odd ones out, as they require accurate simulations of dynamics in all three parts of the hydrological system. Increased understanding of the rate and behavior of groundwater recharge requires the integration of knowledge from watershed hydrology, vadose zone hydrology, groundwater hydrology, ecohydrology, and hydrometeorology.

Groundwater recharge is largely determined by precipitation, runoff, and evaporation from interception, transpiration, soils, and open water (Savenije, 2004). As a result, variations in meteorological and climatic conditions will cause variations in groundwater recharge. After a peak in the number of scientific publications on groundwater recharge in the early 1990s, the recent (2005–now) rise in the number of recharge studies is increasingly related to climate change (Fig. 1). It is envisioned that in the not-so-distant future more prolonged dry periods will alternate with more intensive rainfall events (Solomon et al., 2007). The resulting changes in groundwater recharge will have an effect on soil moisture dynamics (Weltzin et al., 2003; Porporato et al., 2004; Knapp et al., 2008; Bartholomeus et al., 2011) and alter the hydrological system (Wegehenkel, 2009). Increased droughts may affect the future availability of fresh water (Bates et al., 2008). Changes in recharge rates may affect streamflow and surface water quality (Eckhardt and Ulbrich, 2003), and altered recharge paths and rates may affect leaching of pesticides from the surface to the groundwater table (Christiansen et al., 2004).

This special issue on groundwater recharge attracted 7 articles from 28 authors. The range of topics reflects both the broad interest in groundwater recharge and the variety of approaches that are applied to get a handle on this elusive flux. Studies vary in spatial and temporal scale and from focused, process-level investigations to global investigations intended to improve water resource management under climate change.

The smallest scale study is contributed by Cuthbert et al. (2013). They present a careful field examination of recharge processes beneath a plowed field. Their results demonstrate the intricate interplay between diffuse and focused flow processes. The threshold-type activation of preferential flow seen in this study is a prime example of the complex behavior that can arise under unsaturated conditions.

Two papers represent larger scale investigations with direct implications for water resource management. Flint et al. (2012) present an approach to quantify surface and groundwater resources at a large scale, in the face of limited hydrologic and geologic data. The approach is applied to the San Diego Basin, California, USA, but may also be applied to provide much needed estimates in the many ungauged and under-gauged basins throughout the world. This

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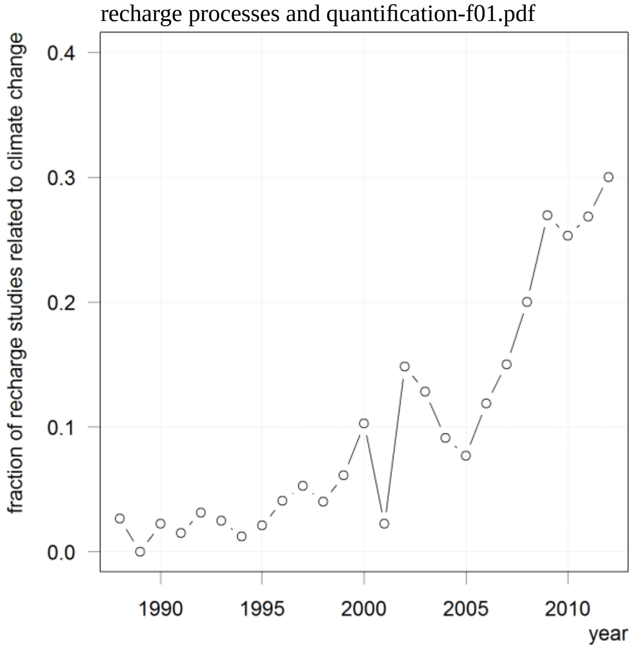

Fig. 1. Number of studies with "groundwater recharge" and "climate change" in the keywords relative to those with only "groundwater recharge". Based on statistics in Scopus as of 24 April 2013.

has implications for development and for the quantification of the hydrologic effects of climate change. Hashemi et al. (2013) present a study with a direct water resource management application. They quantify the impact of artificial recharge through floodwater spreading in Iran and show that this approach can capture four times the natural recharge in ephemeral channels, offering a practical approach to augmenting natural recharge with minimal infrastructure requirements.

The interaction of the vadose zone and plants is addressed by Ahring and Steward (2012), who demonstrate the use of time-lapse aerial photography of riparian vegetation to identify areas of changing recharge. Their work is based on previous studies and new field investigations that relate phreatophyte health to water table depth, and thereby to recharge. This work has clear implications for ecosystem protection and restoration. As the authors suggest, it may also provide a non-invasive measure of water table decline that could be the focus of further investigations.

In line with the current trend, three of the seven papers consider questions regarding the influence of a changing climate on future recharge. Leterme et al. (2012) present a study that is ostensibly aimed at predicting recharge on the millennial scale through a near-surface disposal facility for low and intermediate level short-lived radioactive waste in Belgium. Their investigation relies on the use of numerical modeling of percolation coupled with a unique approach to represent future climatic conditions: climatic analog stations. This thoughtful approach to represent climate change, while retaining the richness of a real meteorological time series, offers excellent opportunities to examine the propagation of time-varying signals through the vadose zone. Dawes et al. (2012) also examine the response of the vadose zone to projected future climatic conditions. Their study uses a range of models of varying complexity to examine the interactions between climate, geology, hydrogeology, and land use to determine how recharge is likely to change under a changing climate. Barron et al. (2012) take a different approach to examine the dependence of recharge on climate, vegetation, and soil properties. They use numerical models to investigate the effect of climate variables on recharge in tropical, arid, and temperate climates. They conclude that rainfall intensity is an important determinant of recharge, as is the seasonality of rainfall; the greatest impact of climate parameters is observed in tropical climates. Importantly, for most scenarios, the percent change in recharge is 2 to 4 times the percent change in annual rainfall.

The papers collected in this special issue represent a smorgasbord of studies on groundwater recharge. The authors applied a variety of techniques at a variety of scales to study groundwater recharge. Taken together, they make a compelling case that improved understanding of recharge is critical for predicting hydrologic responses to climate change and that there is much in this field of study that is still unknown. We believe that this body of work contributes to the state of knowledge on groundwater recharge, and, equally important, we hope that it sparks future research and discussions.

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