

Predicted impacts of land use change on groundwater recharge of the upper Berg catchment, South Africa

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ABSTRACT

Land use change is a major factor influencing catchment hydrology and groundwater resources. In South Africa, the management of scarce water resources is a big concern. The study area, the upper Berg catchment, Western Cape, South Africa, contains strategic water resources. The catchment has undergone many changes in recent years, not least of all the construction of a dam on the upper reach. To reduce water loss due to evapotranspiration, non-native hill slope vegetation upstream of the Berg River Dam was cut down. It was hypothesised that recharge has been increased due to this change in vegetation. The objectives of this study were to determine land use changes in upper Berg catchment using multi-temporal Landsat images from 1984, 1992, 2002, and 2008, and to predict the impact of these land use changes on groundwater recharge. For the simulation of groundwater recharge the distributed hydrological model WetSpa was used. Forest plantations lost 72% (18.8 km²) of their areal extent between 1984 and 2008, due to deforestation as part of a plan to implement the ecological Reserve as required by national water policy; the area of barren land increased by 15.7 km² in the same period. The high increase in precipitation, especially in the period of 2005–2009, combined with the change in land use in the study area resulted in a highly increased (278%) predicted mean groundwater recharge. Simulated groundwater recharge shows strong spatial differences for each evaluated year. The effect of the rapid clearing of non-native hill slope vegetation upstream of the Berg River Dam for the land use scenario of 2008 was tested to check if clearing is an important factor in the increase of groundwater recharge. Hence, we simulated the whole time-series from 1984–2004 (21 years) with the land use map from 2008 instead of the land use maps for 1984, 1992 and 2002. A systematic increase of about 8% per year for the 21-year period, due to the change in land use from the different years to that of 2008, is predicted, which confirms that the clearing of the non-native hill slope vegetation is of considerable importance for the increase in groundwater recharge.

Keywords: Berg catchment, ecological Reserve, WetSpa, remote sensing

INTRODUCTION

Groundwater is considered to be one of the most important, and in many semi-arid areas one of the most scarce, natural resources. Over the past decade there has been an increasing focus on studies, analyses and exploration of groundwater, for the purpose of sustainable exploitation. Policy intention is to maintain a balance between demand, quantity and quality of groundwater. Land use change is a major factor affecting the groundwater system (Calder, 1993). Through history, intense human activities, including industrialisation, mining, urbanisation, agriculture, damming, etc., have resulted in significant and clear changes in the landscape with impact on the water balance of surface and groundwater systems (Bronstert, 2004).

Collecting accurate and timely information on land use is important for land use change detection (Giri et al., 2005) as a basis for predicting impact on water resources. There are various methods that can be used in the collection of land use data but the use of satellite remote sensing technologies can greatly facilitate the process (Gautam et al., 2003). Compared with traditional ground-based surveys, satellite remote sensing provides greater amounts of information on the geographic distribution of land use in a relatively cost- and time-saving way for

assessments on a regional scale (Kachhwala, 1985; Rogan and Chen, 2004; Yuan et al., 2005). Space-borne remotely sensed data may be particularly useful in developing countries where recent and reliable spatial information is lacking (Dong et al., 1997). Remote sensing technology and geographic information systems (GIS) provide efficient methods for analysis of land use issues and tools for land use planning and modelling (Star et al., 1997; Chilar, 2000). By understanding the driving forces of land use development in the past, managing the current situation with modern GIS tools, and modelling the future, one is able to develop plans for multiple uses of natural resources and nature conservation. Ringrose et al. (2005) stressed the need to map land use and land-cover change in Africa, as, already more than a decade previously, land use change was accelerating and causing widespread environmental problems. This changing pattern of land use and land cover reflects changing economic and social conditions taking place throughout the continent. Monitoring such changes is important for coordinated actions at national and international levels (Bernard et al., 1997).

Different methods have been developed for land use change detection. Yuan et al. (1998) divide the methods for change detection and classification into pre-classification and post-classification techniques. The pre-classification techniques apply various algorithms directly to time-series satellite imageries to generate 'change' versus 'no change' maps. These techniques locate changes but do not provide information on the nature of change (Singh, 1989; Ridd and Liu, 1998; Yuan et

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