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Assessing SWAT models based on single and multi-site calibration for the simulation of flow and nutrient loads in the semi-arid Onkaparinga catchment in South Australia

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ABSTRACT

Distributed catchment models such as SWAT (Soil and Water Assessment Tool) are widely used to assess catchment characteristics and facilitate informed decisions for safeguarding water quantity and quality. This study applied SWAT to simulate monthly stream flow and loadings of total suspended sediment (TSS), total nitrogen (TN) and total phosphorus (TP) for five monitoring stations within the Onkaparinga catchment, and tested the models' performance based on single-site or multi-site calibration.

The results showed that multi-site calibration did not improve simulations of flow and sediments compared to single-site calibration. However, simulation results for TN and TP loads improved in both rural and urban sub-catchments of this catchment. Uncertainty analysis revealed that there is high uncertainty in model simulation of TSS by both strategies. The study has demonstrated: (1) the capability of SWAT to simulate realistically the extreme flow conditions of the semi-arid Onkaparinga catchment; (2) the benefit of local monitoring data for more realistic simulations of nutrient loads by means of the multi-site calibration of SWAT as pre-requisite for scenario analysis of spatially-explicit management options.

1. Introduction

Successful catchment management seeks compromises between conflicting land-uses and the quantity and quality of water received by downstream reservoirs. Process-based distributed catchment models such as SWAT prove to be useful tools for achieving this task (Daloğlu et al., 2012; Karamouz et al., 2010; Mateus et al., 2014; Nielsen et al., 2013).

The rural Onkaparinga catchment in South Australia feeds into the Mount Bold and Happy Valley reservoirs that contribute to the drinking water supply for the metropolitan area of Adelaide. It is not only affected by the arid climate of South Australia with high variability of rainfall and periods of drought but also by intensive horti- and viticulture. Since eutrophication of the reservoirs is a major concern for safe drinking water supply, improved understanding of spatial and seasonal nutrient dynamics within the catchment is prerequisite for preventative eutrophication management. This knowledge can be gained from application of distributed catchment models that take spatial heterogeneity explicitly into account.

Distributed catchment models require careful model calibration and validation procedure. Several authors have demonstrated the effectiveness of multi-site calibration over the single-site calibration centring solely on data of the catchment outlet (Chiang et al., 2014; Daggupati et al., 2015; Moussa et al., 2007; Qi and Grunwald, 2005; Wang et al., 2012) including successful applications of SWAT for nested and non-nested catchments (Cao et al., 2006; White and Chaubey, 2005). In contrast, some authors have reported no significant improvements by multi-site compared to single-site model calibration (Khakbaz et al., 2012; Reed et al., 2004). A similar conclusion was reached by Lerat et al. (2012) after applying four different calibration strategies including both single-and multi-site to 187 French catchments. Given these conclusions, it raises a question whether multi-site calibration really outperforms the single site calibration.

Hence this study aimed to identify if there is any significant improvement in SWAT model performance by multi-site calibration strategies at both watershed outlet and interior points. Compared to previous studies that focused on only stream flow comparisons, this study also highlights the comparison between

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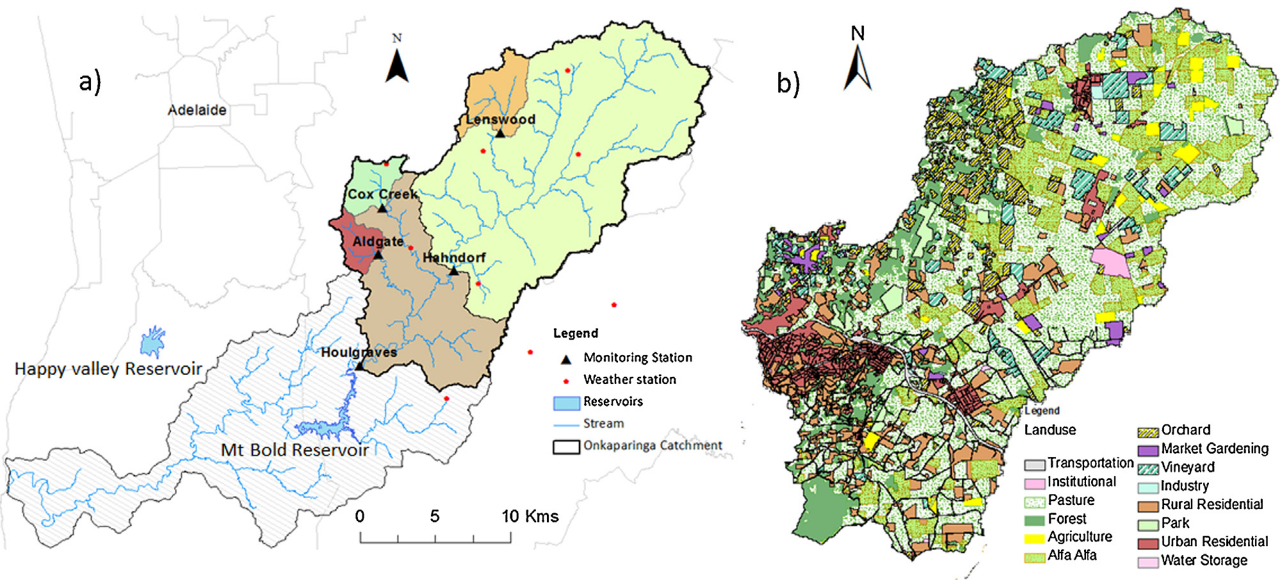

Fig. 1. The Onkaparinga Catchment. (a) Delineation map and monitoring stations. (b) Land use map.

the two calibration strategies for simulation of loadings of suspended solids, total nitrogen (TN) and total phosphorus (TP) of the Onkaparinga catchment by means of SWAT.

2. Materials and methods

2.1. Study area and data

The Onkaparinga catchment is situated east of Adelaide with an area of 535 km^2 and an elevation range from 10 to 700 m. This study applied to an area of 317 km^2 upstream of the Houlgraves gauging station of the Onkaparinga catchment (see Fig. 1a).

The Mediterranean climate of South Australia is characterized by dry summers and winter rainfall between 522 mm in the coastal and 1088 mm in upland areas (Westra et al., 2014). Mixed land uses of the catchment include horti-, viti- and agriculture, where farm dams typically serve for irrigation. A pipeline from the River Murray releases water into the Onkaparinga River downstream of Hahndorf (see Fig. 1a) that contributes approx. 87% (19952 ML) of the total flow during the dry season (Nov–April) and approx. 24% (45310 ML) during the wet season at Houlgraves.

The geological formation of the western part of the catchment consists of permeable sandstone and quartzite while the eastern part is underlain by less permeable siltstone and metasediments (Zulfic et al., 2002). The subsoil is clayey in texture on the lower slopes and flats of the catchment and may prevent water drainage. The hill slopes have clayey to sandy subsoils mainly utilized for horticulture and viticulture.

A Shuttle Radar Topography Mission (SRTM)- derived Digital Elevation Model (DEM) with a resolution of 30 × 30 m (Geoscience Australlia, 2011) was used to delineate the catchment and calculate important topographical parameters such as slope, channel dimensions and overland field length where a 1:100,000 land-use map of 2003 (see Fig. 1b) was used. The base data of the soil map of 2005 provided by the Department of Water, Soil and Natural Resources of South Australia has been compiled at scales of 1:50,000 or 1:100,000. The data attributes of the soil were extracted from the Australian Soil Resource Information System (ASRIS, 2013). Ten meteorological stations within and adjacent to the catchment were used. Since there were missing data for all the stations from the publicly available website of the Bureau of Meteorology, daily SILO

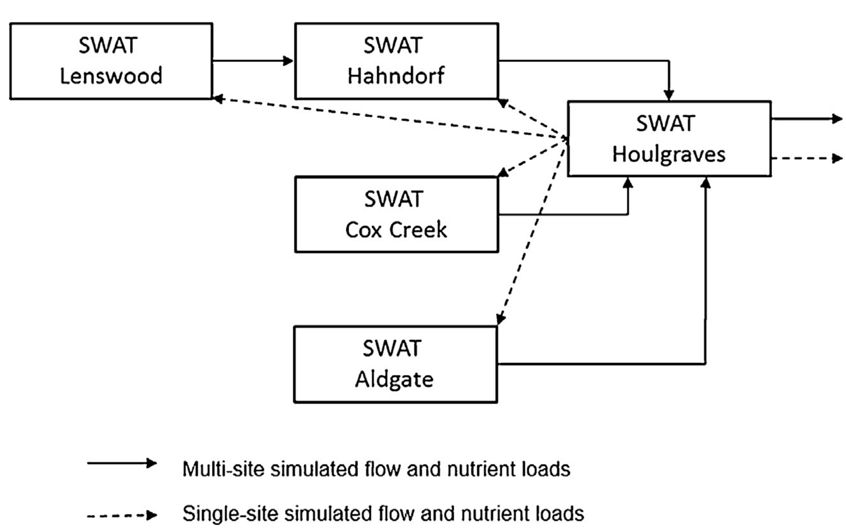

Fig. 2. Conceptual diagram of the multi-site and single-site approaches for modelling the Onkaparinga catchment by SWAT.