Water quality monitoring with high temporal resolution in a forested catchment and optimization of loading and solute concentration model

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Introduction

This study discusses on the long-term water quality monitoring with high temporal resolution in a forested small catchment using flow injection potentiometry and the multi-objective optimization of a conceptual hydrological model for simulating streamflow, loading and solute concentration.

Study Catchment, Water Quality and Hydrological Data

Study area is the forested experimental catchment of 12.14 ha located in Gojo city, Nara prefecture, Japan. Precipitation data were observed by tipping bucket rain gauge and streamflow data were observed by V-notch weir and water gauge at outlet of the catchment. Moreover, an in situ flow injection potentiometry (FIP) system to monitor the stream water quality (potassium, sodium and chloride) every 15 minutes for two weeks was developed and applied to the catchment (Tada et al., 2006). The precipitation and stream flow data every 10 minutes and daily potential evapotranspiration from May, 2007 through April, 2011 and sodium concentration data every 10 minutes estimated by liner interpolation from June, 2009 through April, 2011 were used to calibrate the loading model and solute concentration model.

Loading and Solute Concentration Model and its Optimization

The Long- and Short-Term Runoff Model (LSTRM, Kadoya and Nagai, 1988) composed of three storage tanks was used for streamflow simulation. The LSTRM has 14 parameters including 3 initial storage depths. The LSTRM combined four LQ equations of power type was used for simulating sodium loading and the LSTRM combined four CQ equations of power type was used for simulating sodium concentration. The four LQ equations (CQ equations) have 8 parameters and total number of parameters to be calibrated is 22. In this study, the 22 parameters were estimated by the following three steps based on the compromise programming (Yu, 1973; Zeleny, 1973; Tanakamaru and Fujihara, 2006). The minimization of Root Mean Square Error (RMSE) using SCE-UA method (Duan et al., 1992) was applied in each step. Step 1: Firstly 14 parameters of the LSTRM were estimated by streamflow data and secondly 8 parameters of LQ (CQ) equations were estimated by sodium loading data (sodium concentration data). Step 2: 22 parameters were estimated by using only sodium loading data (sodium concentration data). Step 3: Firstly, the objective space composed of horizontal axis of streamflow RMSE and vertical axis of loading RMSE (concentration RMSE) were set and the ideal point were plotted by RMSE values in step 1 and step 2. Secondly, the compromise solution is determined by minimizing the weighted Euclidian distance between the ideal point and a search point in the objective space.

Results

The Model-1, Model-2 and Model-3 were obtained in step 1, 2 and 3, respectively. The results of sodium loading simulation are summarized as follows: (1) Model-1 showed the smallest RMSE of streamflow and the largest RMSE of sodium loading in three models. (2) Model-2 showed the largest RMSE of streamflow and the smallest RMSE of sodium loading. (3) Model-3 showed the streamflow RMSE close to Model-1’s error and the loading RMSE close to Model-2’s error. The Model-3 optimized by the compromise programming can be evaluated the best by the comprehensive assessment of simulated streamflow and sodium loading. The overall results of sodium concentration simulation were similar. The time series of streamflow, sodium loading and sodium concentration estimated by Model-3 showed

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good agreement with observed ones.

Keywords: water quality monitoring, flow injection potentiometry, loading and solute concentration model, Long- and Short-Term Runoff Model, multi-objective optimization, compromise programming

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