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Modelling soil erosion and its response to the soil conservation measures in the black soil catchment, Northeastern China

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A B S T R A C T

The black soil in Northeastern China is experiencing severe soil erosion. However, spatially distributed erosion models have scarcely been used to identify the sediment source of a catchment as well as its response to the implemented soil conservation measures (ISCMs). In this study, the WaTEM/SEDEM model was selected and calibrated with sediment yields (*SY*s) from 25 reservoir catchments in Baiquan County. The validated model was applied to the Shuangyang river catchment to simulate soil erosion, *SY* and their responses to the ISCMs. The model simulation accuracy was measured by Nash-Sutcliffe efficiency (*NSE*) and relative root mean square error (*RRMSE*). A satisfactory result was obtained with *NSE* of 0.914 and *RRMSE* of 0.266, respectively. The ISCMs on the farmlands in Shuangyang river catchment greatly reduced sediment delivery to the rivers. The terraced and contour tillage lands became sediment sink and the up/downslope tillage land had lower erosion risk, resulting from the ISCMs on the upper slopes. However, these measures are not effective enough to comprehensively control soil erosion. The erosion rates in the erosion areas within terrace and contour tillage land were still very high. The large area of up/downslope tillage land and the steep slopes with gradients above 25% still suffered severe soil loss. Comprehensive soil conservation should be urgently applied to reduce soil erosion and sediment delivery to the rivers. This study can help guide effective implementation of soil conservation measures at the catchment scale for the black soil region, Northeastern China.

1. Introduction

Soil erosion is a severe environmental issue. It causes both on-site soil and nutrient losses in agricultural lands and off-site water pollution, lake and reservoir sedimentation, and channel and harbor silting (Ferguson, 1986; Gardner and Kjerfve, 2006; Zhang et al., 2013; Ma et al., 2014; Fang, 2015). In the black soil region of Northeastern China, severe soil loss has occurred since the 1950s (Liu et al., 2010). The depth of the black soil has reduced from 60 to 70 cm during its original cultivation period to 20–30 cm today (Fan et al., 2005; Fang et al., 2012). In some places, the black soil layer has been completely eroded away. If this problem is not adequately solved, all the fertile black soil could be completely eroded away within 100 years (Fan et al., 2005).

The Chinese government has recognized the seriousness of this problem and conducted extensive campaigns in past decades. For example, prior to 2008, around 1.1 billion RMB was invested to control black soil loss. During 2008–2010, 426 million RMB was used to improve farming methods in sloping lands (Liu et al., 2011). Under these campaigns, large areas of the black soil region have been implemented with multiple soil conservation measures (Xu et al., 2010), among which terrace and contour tillage are the two most frequently employed measures on sloping farmlands (Fan et al., 2005; Wei, 2007). Fully understanding impacts of these soil conservation measures on soil erosion and sediment delivery at the catchment scale is vitally important to effectively implement integrated catchment management.

Soil erosion modeling is an efficient method to simulate soil erosion, to identify sediment source areas, and to evaluate soil conservation measures. Over decades, many soil erosion models, such as Water Erosion Predict Project (WEPP; Nearing et al., 1989), Soil and Water Assessment Tool (SWAT; Neitsch et al., 2011), and EROSION 3D (Schmidt, 1990), have been used to simulate erosion. Although these models have been successfully used around the world, most of the structures of the physical erosion models are complex with several parameters being required to be calibrated (Jetten et al., 1999; De Vente et al., 2013). The Water and Tillage Erosion Model and Sediment Delivery Model (WaTEM/SEDEM) is a

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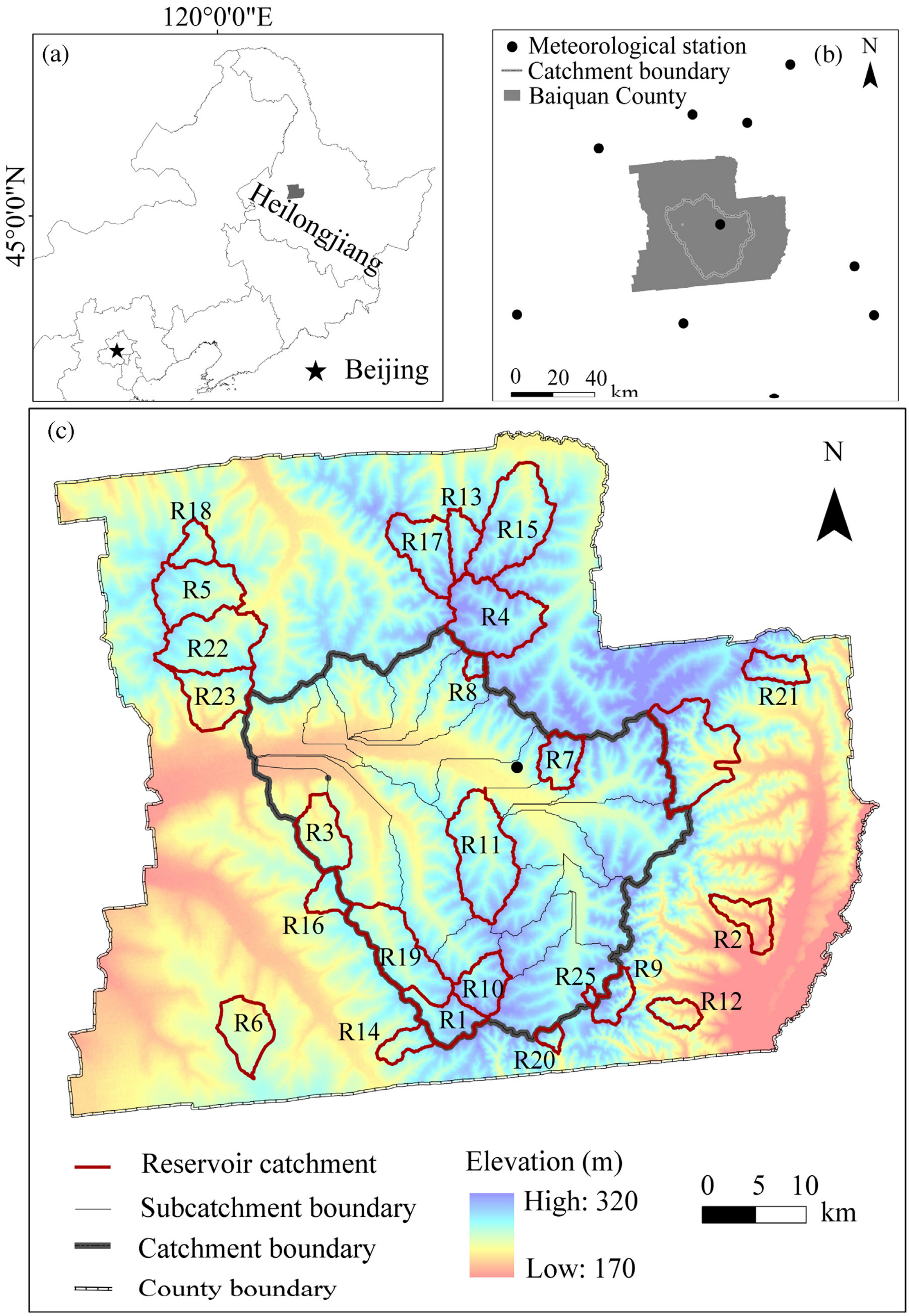

Fig. 1. Information of the study area: (a) Locations of Baiquan City in China and its boundary, (b) the meteorological stations and the Shuangyang river catchment, and (c) the 19 subcatchments of the Shuangyang River catchment and the 25 reservoir catchments R_i (i = 1, 2. . . . , 25) corresponds to the counterparts in Table 1.