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Development of the landslide-integrated SWAT model

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With the steep topography and fragile geology, Taiwan often encounters with natural disturbance, e.g., typhoons and earthquakes, leading disasters in landslide-prone areas. During storm and typhoon events, landslide contributes the majority of the sediment loads in the watersheds of Taiwan. The sediment from landslide might change the stream morphology, hydrologic processes, sediment transportation, and in-stream water quality. Therefore, it is important to consider the landslide sediment contribution in watershed management. The hydrological model is an efficient way to evaluate the impacts of the climate change, land use/land cover change, and the policy of watershed management on hydrology and water quality in a watershed. Among these hydrological models, the soil and water assessment tool (SWAT) model, developed by the USDA-Agricultural Research Service in 1994, has been widely used and modified for local needs in the world. Although the SWAT model could effectively simulate the long-term watershed responses, namely discharge, sediment, nutrient, and pesticide loads under different climate or land use management scenarios, the sediment loads during extreme rainfall events are usually underestimated. In this study, we aimed to:
(1) integrate the landslide module in the SWAT model to improve the sediment simulation performance; (2) identify the characteristics of landslide-induced sediment events by calibrated landslide triggers and sediment transport parameters; (3) compare the model performance of the original SWAT model and the integrated model; (4) estimate the sediment contribution by landslide events.

The Xiuguluan River basin (XRB), located in eastern Taiwan, is selected as the study area. The XRB has an area of 1786.5 km^2 with the elevation ranging from 0 m to 3700 m. As the steepest river in Taiwan, the Xiuguluan River with the stream gradient of 1/34 result in rapid headwater erosion in the basin. Based on the landslide record during 2004-2017, the landslide areas occupy 2.1% of the XRB, bringing significant amount of sediment into the Pacific Ocean. Moreover, compared to the average annual precipitation (~ 1900 mm) in the XRB, the largest 2-day accumulated precipitation of a single event was 785 mm record in 2000 when the Xangsane typhoon occurred.

The SWAT model simulation is based on the hydrologic response units (HRUs), a unique combination of land use/land cover, soil and slop in a subbasin. The simulation results at HRU level can provide components of water balance, sediment yield, and nutrients yield. The development and examination of the landslide module integrated in the SWAT model contains two parts: identification of landslide triggers and improvement in sediment yield estimation. The landslide triggers considered in this study include: land use/land cover, daily precipitation, and soil water content. The historical landslide maps from 2004 to 2017 were used to identify and verify the classified landslide in the long-term investigated land use/land cover data. The daily precipitation data were collected from Central Weather Bureau (CWB), Taiwan. Besides observed land use/land cover and precipitation data, the simulated soil water content was obtained in the SWAT model. In order to evaluate the improvement of the integrated model, four landslide volume equations suggested by Soil and Water Conservation Handbook (Soil and Water Conservation Bureau, 2017) were examined for sediment yield estimation.

Based on the preliminary results, the SWAT model could simulate the discharge well in the XRB, but underestimated in peak flow and high sediment condition. By integrating the landslide module in the SWAT model, better performance in sediment loads was found in high sediment condition, indicating the landslide triggers could well reflect the characteristics of landslide areas and its impact on sediment loads, and the sediment yielded by landslide was successfully calculated by the landslide volume estimation equations. The next step to further improve the sediment loads at the watershed outlet is to examine different sediment transport equations in the landslide-integrated SWAT model with consideration of the change in channel morphology.

Keywords: SWAT, landslide, sediment yield modeling