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Future change of rainfall prone to sediment disasters in Japan based on critical line method with bias-corrected regional climate projections

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Background

This study aims to examine future trends of rainfall events prone to landslide and sediment disasters under climate change impact from a considerable number of projections of multiple regional climate models. Global warming is affecting our living environment by altering climatological conditions more extreme than ever before. In the recent decade, people have experienced many events of short-duration intense torrential rainfall and long-lasting Baiu rainfall in record-breaking amounts around the whole Japan beyond our past living experience. These extreme rainfall events consequentially triggered disastrous flood inundation in the lower plain area as well as landslides and debris flows in mountainous area. The official annual reports of sediment disaster have indicated that more than hundreds of landslide disasters have continuously occurred in every year since 2014 and increased more in the last five years (Ministry of Land, Infrastructure, Transport and Tourism, and is abbreviated as MLIT). For the safety of our living environment, we are keen to explore and assess the future tendency of landside risk under this irresistible global warming in a changing climate.

Many practical methodologies for landslide risk estimation have been proposed in terms of different fields. As we attempt to reveal the connection between landslide risk and climate change influence, we adopt the famous hydrometeorological approach, called Critical Line (abbreviated as CL) method, to estimate landslide risk (Osanai et al., 2010). To predict landslide occurrence, the CL method utilizes two hydrometeorological factors of hourly rainfall and soil-water index and a corresponding criterion curve in each 1-km squared mesh over the whole Japan. The criterion curve is just the critical line, and calibrated by historical observed rainfall and landslide events in each 1-km mesh specifically. With a great number of successful predictions of real events, the CL method is currently being applied for nationwide practice of flood and sediment disaster early warning in each prefecture in the whole Japan. This statistically based CL method is currently considered one of the best precise methods for us to identify any rainfall event which has higher risk of landslide occurrence at any specific mesh.

By applying the CL method to the datasets of NHRCM05, one 5-km regional climate simulation (RCM) datasets published by Meteorological Research Institute of Japan Meteorological Agency (JMA), we have successfully revealed the future change of nationwide landslide risk by performing the intercomparison of extracted hazardous rainfall events between the present and future datasets (Wu et al., 2020). However, there are two deficiencies required to be overcome. The first obvious deficiency is that the ensemble number of NHRCM05 is not sufficient to provide a reliable probabilistic assessment. The second is that our previous analysis only explains the relative future change by NHRCM05, but cannot provide the relationship between real conditions. Also, because the critical lines are calibrated using real rainfall observation, the simulated rainfall from RCM has to be bias-corrected by the real rainfall observation for the better usage of the CL method. Therefore, this research aims to correct the simulated rainfall datasets and achieve a reliable assessment of landslide risk using more simulation datasets.

Data and processing

For the purpose of bias-correction, we used the JMA radar/raingauge analyzed precipitation, or called JMA Radar-AMeDAS precipitation. To match the 1-km spatial resolution for all the critical lines, we used the Radar-AMeDAS data from 2006 to 2019 (14 years in total) in the temporal resolution of 30 minutes. As the major advantage, the grid system of the reanalyzed precipitation perfectly match with the one of CLs. For reflecting the future climate, we used the datasets of NHRCM05 and NHRCM02, which is the other RCM datasets in the spatial resolution of 2 km. Each RCM includes one member of present climate (SPA), one future member under the RCP2.6 scenario (SFA_rcp26), and the other four future members of RCP8.5 (SFA_c1, SFA_c2, SFA_c3, SFA_en). Each dataset has the simulation period of 20 years. Only the parameter of surface precipitation in the all period is considered in our analysis.

Landslide risk threshold - Critical Line Method

The study utilizes the latest CL information in all of the 3rd geographical mesh defined by MLIT in the whole Japan.

Bias correction method

Bias correction is performed based on daily precipitation. As the data period of JMA Radar-AMeDAS is shorter than the simulated rainfall from RCM, we follow a recent method based on the concept of scaled distributions mapping (Switanek et al., 2017) to retain the features of return period of daily precipitation between the observation and simulations. We set 0.5 mm as the threshold of daily precipitation due to the minimum output of rain gauge measurement. The cumulative distribution functions (CDF) of daily precipitation of observation, present and future simulations are derived from the total data periods. The scaling factor of precipitation values between the present and future simulations is obtained using the corresponding fitted CDFs. Then, the initial bias-corrected precipitation values are determined using the scaling factor multiplied by observed precipitation ones in a scaled CDF that retains the same return period distribution. The expected future model rainy day is adjusted based on the ratio of rainy days to total days in the data period between the present simulation and observation. Finally, the bias-corrected precipitation values are placed back into the simulated time series in the corresponding temporal location. This replacement is performed from the largest values in the descending order to the end of the adjusted future rainy days, and to fill zeros if future projections overestimate future rainy days.

Current and expected results

Based on the bias correction method, this research would fairly assess landslide risk by summarizing the extracted and bias-corrected rainfall events from large numbers of datasets of different RCM.

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