Estimation of sediment disaster risk around the Fuji River Basin using a machine learning method that considers trigger and inherent factors

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Many regions within the Fuji River Basin are vulnerable to sediment disasters. The Fuji River flows through Shizuoka, Yamanashi, and Nagano prefectures and includes the Itoigawa–Shizuoka structural line. As a non-structural countermeasure, the Japan Meteorological Agency (JMA) and prefectural governments operate the Sediment Disaster Alert Information System, which considers detailed rainfall information based on weather radar to determine trigger factors of sediment disasters. However, this system does not directly consider inherent factors such as slope gradient and land surface geology. It is therefore necessary to develop a sediment disaster risk estimation method that considers both trigger and inherent factors.

In this study, we developed a method to estimate sediment disaster risk that considers trigger and inherent factors in the areas around the Fuji River Basin (Yamanashi and Shizuoka prefectures) using neural network and k-means method. The targets of this method are shallow landslides, including debris flows and large slope failures.

As a target for training and validation, we selected the typhoons ROKE (September 21, 2011) and TALAS (September 2-4, 2011), which caused severe damage due to sediment disasters in Yamanashi and Shizuoka prefectures. To determine the inherent factors, we collected 1-km-resolution data for Yamanashi and Shizuoka prefectures using the Elevation Degree of Slope Tertiary Mesh Data, Land Use Tertiary Mesh, and Land Classification Mesh (surface layer geology) products from National Land Numerical Information. To obtain trigger factors, we extracted 60-minute accumulated rainfall (ca. 1-km resolution) from C-band radar data provided by the JMA. We also calculated the soil water index (SWI) using the 3-layer tank model. As training data, we used the occurrence of shallow landslides within each 1-km cell based on disaster reports provided by Yamanashi and Shizuoka prefectures. In this dataset, cells where shallow landslides occurred were assigned a value of 0, and those where shallow landslides did not occur were assigned a value of 1.

We began with binary classification, using a neural network to output values from 0 to 1. We then inputted trigger factors (2 elements) and inherent factors (30 elements) to the neural network. The error (loss function) of the training process did not decrease as epochs increased, due to the presence of several 0 values in the training dataset, which indicated a lack of sediment disaster. We then applied an undersampling method to the input data; however, the error still did not decrease.

In the next step, we reconstructed the neural network (which had two hidden layers) for a regression problem using risk levels from 0 to 1 for each 1-km cell as training data. The input data were classified into 40 clusters using the k-means method, and the risk level for each cell was determined based on the ratio of sediment disaster occurrence cells in each cluster. To equalize the weights of the trigger and inherent factors used in the k-means method, two trigger factors (60-minute accumulated rainfall and SWI) and two inherent factors (slope gradient, fault presence) were selected. The error of the training process (using data for 15:00 Japan Standard Time [JST], September 21, 2011) decreased as the number

of epochs increased. In the validation phase (using data for 11:00 JST on September 3, 2011), the neural network output showed high values in cells where debris flows actually occurred.

In conclusion, we found that the outputs of the proposed method can be used to determine sediment disaster risk. Adequate selection of input data was important to the validity of the results, as was assignment of equal weight to trigger and inherent factors. Future studies should increase the number of sediment disasters used in the training process.

Keywords: Sediment disasters, Neural network, Clustering, Inherent factors, Trigger factors