Effect of Soil Layer Thickness on Flood Discharge in Small Mountainous Watersheds

*Sotaro Hiroki[1], Yuko Asano[2], Takashi Oguchi[3]

1. Department of Earth and Planetary Science, The University of Tokyo, 2. The University of Tokyo, 3. Center for Spatial Information Science, The University of Tokyo

In recent years, severe floods due to heavy rains happened in various places. River water is generally originated from rainwater that falls on mountain slopes, passes through the underground, and finally springs out. Numerous studies have been conducted to elucidate the process of underground water flow in sloping terrain, and it has been clarified that preferential flow in pipes in the topsoil layer is dominant during rainfall. However, there is little research on the effect of non-uniform soil layer thickness on flood discharge, and a unified view has not yet been obtained. The purpose of this study is to investigate the effect of soil layer thickness on flood discharge and to clarify the relationship between them.
We first selected a small watershed "Bakemonozawa" in the Chichibu Forest (41.1 ha) in the University of Tokyo Forest, Japan. The watershed is underlain by Mesozoic-Paleozoic sedimentary rocks. In this watershed, continuous measurements of river flow and precipitation have been conducted. We investigated the soil layer thickness and soil moisture properties along ridges and valleys.
QGIS software was used to analyze watershed characteristics. The area of each small watershed was calculated from the 10-m DEM provided by the Geospatial Information Authority of Japan. We also estimated the spatial distribution of soil thickness and the elevation of the bedrock surface by combining the DEM and the soil thickness data. Next, to calculate the outflow from the soil layer, HYDRUS-1D software was used, which can calculate vertically saturated and unsaturated flow based on physical laws. Using the observed precipitation, soil properties, and soil layer thickness, the software can calculate the amount of outflow from the bottom of the soil layer using the finite element method. This study assumed that the flood discharge can be explained by vertical flow in the soil layer, and the observed discharge waveform was compared with the calculated waveform.
Along the valleys and the ridges of the watershed, the soil layer thickness ranges from 0.5 to 1.5 m and 2 to 3 m, respectively, and the soil moisture properties also differ greatly. With a change in soil layer thickness from 0.5 and 3 m, the hydrograph of the calculated outflow changes markedly. The larger the soil layer thickness, the smaller the intensity of the calculated outflow at the lower end of the soil layer, and the larger the time difference between the peaks of precipitation and surface flow. The outflow hydrographs were calculated using the soil moisture properties for the valleys and the ridges, respectively, and the differences in the outflow hydrographs were investigated. No significant differences were found in the calculated runoff volumes, suggesting that the soil layer thickness significantly affects the shape of the hydrograph.
We plan to use the same method for two other watersheds in Japan: "Fukuroyamasawa" in the Chiba Forest (2.0 ha, underlain by Tertiary sedimentary rocks), and "Shirasaka" in the Ecohydrology Research Institute (2.6 ha, Cretaceous-Paleogene weathered granitic rocks). We expect a more accurate reproduction of groundwater flow because detailed soil thickness data are available. We will also investigate the relationship between the soil layer and the bedrock because previous studies in these watersheds pointed to significant groundwater infiltration into the bedrock.

Keywords: flood discharge, soil layer thickness, groundwater, small mountainous watersheds

