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Hydrologic, soil, and topographic characteristics of a landslide site in Okaya City, Nagano Prefecture

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The widespread landslide-debris flows that occurred in Nagano Prefecture west of Suwa Lake in July 2006, left 13 dead, injured, and lost people, and caused a tremendous amount of economic loss. Because most of these landslides occurred on relatively gentle slopes during low intensity rainfall, controversy exists regarding the actual failure mechanisms. Therefore, our objective is to understand the mechanisms of these destructive landslides by focusing on hydrological response and mechanical properties of the soil. Field studies at the smaller scale showed that soil structure and topographic features of two selected landslides may have a significant effect on the occurrence of these failures. Herein we present findings of initial investigations based on topographic, hydrologic, and soil characteristics of these landslides.

At first, a study focused on the soil structure and profile soil was conducted by excavating slices in a soil pit at the head of one of the landslides (Fig. 1). The dominant soil mantle of the hillslopes in the study area is ash from a neighboring volcano (Ontake). These field excavations revealed that the vertical structure of the soil is remarkably heterogeneous and consists of four distinct layers (from top to bottom): a dark surface layer of organic-rich soil, a lighter colored soil of original volcanic ash, a black layer of highly organic-rich subsoil, and an old volcanic ash layer continuing down to the tuff bedrock.

Because of the highly heterogeneous nature of the soils, the research was expanded to conduct extensive hydrological investigations. The landslide event on July 19, 2006 was triggered by a 3-day rain storm with total precipitation exceeding 330 mm. Saturated hydraulic conductivity (K_{sat}) measured in undisturbed soil cores from the main scarp of the failure showed a clear pattern with depth and soil type. The high variability of the K_{sat} values in the upper soil may be evidence of preferential flow paths, whereas the K_{sat} values around the zone of the black layer were more uniform. Moreover, soil depth varies from point to point; thus, bedrock is reasonably mapped using a knocking cone penetrometer.

The most remarkable feature in this area is the topography. From several decades ago, a long history of farming was practiced on these hillslopes. These anthropogenic practices included terracing and cultivation, which changed the indigenous slope geomorphology and possibly affected slope stability by diverting or concentrating surface and subsurface flow onto particular portions of hillslopes.

Preliminary findings suggest that hydrological modeling is needed to explain the mechanisms of slope failure and consequently predict the instability of hillslopes in this area. Such models must account for heterogeneities in soil properties and topography.

Fig. 1. Slice excavation in a soil pit