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A review of landslide hazards in Japan and assessment of their susceptibility using an analytical hierarchic process (AHP) method

Abstract In spite of its small size, Japan suffers many landslide disasters due to intense rainfall and earthquakes. This article describes the distribution and topography of these landslides, and a new method of evaluating the susceptibility, the analytical hierarchic process (AHP). The method assigns scores to each factor of micro-topography of landslide-prone areas identified in aerial photographs, and assesses the susceptibility of landslide from the total score. In addition, a method of simulating sliding mass runout is briefly presented for the designating sediment-related disaster warning areas.

Keywords Landslide distribution · Landslide susceptibility assessment · Sliding mass runout

Types and damage situation of sediment–related disasters in Japan

Kinds and classification of sediment–related disasters

Japan has a total land area of 370,000 km², of which 70% is mountainous. Although this is only 0.1% of the earth's land area, over 10% of all active volcanoes (86) are located in Japan, and the country accounts for about 10% of the world's seismic energy emission. In addition, Japan receives annual precipitation of 1750 mm, which is almost double the annual global average, and is struck by approximately 11 typhoons every year. Thus, the country is prone to sediment-related disasters.

Sediment-related disasters in Japan vary in morphology depending on whether caused by rainfall, snow melt, earthquake, soil, geological structure, topography, or other factors. Sediment-related disasters can be classified either legally or academically. The legal classification is: debris flow, landslide and slope failure, based on differences in damage features, investigation methods and prevention countermeasures. This classification is based on the fact that Japanese people have long distinguished between "flow", "slide" and "collapse" of earth masses according to the speed of travel, distance traveled, size and physical properties of traveling soil mass, possibility of recurrence, and other traveling morphologies. Landslides and slope failures are distinguished as shown in Table 1.

Sediment-related disasters are classified according to this table by engineers of governmental bodies, and prevention and evacuation measures are taken based on the Landslide Prevention Law and the Law for Prevention of Steep Slope Failure Disaster. Municipal governments then inform local residents of the landslide-risk areas identified. Academically, the classification by Varnes (1978) is used.

States and characteristics of sediment-related disasters

The frequency of sediment-related disasters is affected by the occurrence, scale, and intensity of triggers, such as earthquakes, volcanic activity, storms, and snow melting. Sediment-related disasters have been more frequent in recent years probably due to abnormal local downpours, which may be attributable to global warming, and frequent earthquakes such as the large shallow direct-hit earthquake in Niigata-Chuetsu (M=6.8) in 2004. Recent sediment-related disasters have also tended to affect city residents possibly due to residential development in mountainous areas, and some large-scale debris flows caused by deep-seated collapses have killed many people. Earthquakes have also caused many sediment-related disasters.

The number of each class of sediment-related disaster is shown in Fig. 1. The number of disasters shown in this figure is by the legal classification and includes small slope movements of less than 50 m in length and 20 m in width. Many slopes consisting of pyroclastic flow deposit and weathered plutonic granite have collapsed during typhoons and storms in the rainy season. Landslides are few but have caused serious damages due to their large scale. The damage caused to people by each class of sediment-related disaster is shown in Fig. 2. Debris flows, which are fast, have killed many people, while landslides, which are slow, have affected few. Figure 3 shows the generation morphology of sediment-related disasters for each trigger. Many landslides are triggered by prolonged rain and snow melt, and debris flows and slope failures are triggered by intense storms and local downpours during typhoons.

Laws for preventing sediment-related disasters and offices in charge of taking countermeasures

Risk areas where measures should be taken to prevent debris flows, landslides and slope failures are designated by the ministers in charge and prefectural governors under the Sabo Law, Forest Law, Landslide Prevention Law, and the Law for Prevention of Steep Slope Failure Disaster. Designated areas are those susceptible to sediment-related disasters that may directly affect people's lives and houses. In these areas, countermeasures are taken by the national and/or prefectural governments, and warning and evaluation systems are built. The number of designated landslide prevention areas in Japan and their areas are shown in Table 2. The Ministry of Land, Infrastructure and Transport is responsible for risk areas where landslides may damage rivers and highways, and the Ministry of Agriculture, Forestry and Fisheries for areas where landslides may damage forests and farmlands. Thus, areas where landslides may directly damage people and facilities are designated as landslide prevention areas, and there are many such areas throughout Japan.

Distribution of landslide hazard areas in Japan and their topographic and geological characteristics

The geology of Japan mainly consists of granite and metamorphic rock of the Paleozoic to Mesozoic Eras, Tertiary sedimentary rocks, volcanic rocks, and Quaternary volcanic sediment. These strata are cut into blocks by a great number of faults, and the small land area is divided into many geological zones arranged in mosaic patterns