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Landslides induced by heavy rainfall in July 2012 in Northern Kyushu District, Japan and the influence of long term rainfall increase comparing with the slope destabilization due to strong seismic shaking

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1. Objective
We had a deluge in July 2012 in the northern Kyushu district with intense rainfall of 800mm and 108mm/hr. This intensity yielded countless traces of debris flow and landslides, slope failures that induced tremendous damage and causalities in the area. Hence, several field investigations and reconnaissance tasks were conducted to delve into this sediment-related disaster. The various results and the information obtained through this investigation were reported, mentioning the damage, the meteorological condition, geologic-geomorphologic features and hydraulic characteristics of the debris flows, vegetation effects, and the influence of the climate change.
Increase in rainfall that may be induced by the global climate change is obvious in Kyushu district, Japan, according to the analysis of rain data observed in various locations including mountainside points that are not influenced by local warming due to urbanization. On this point of view, we are intrigued to elucidate the response of landslide to this increase in rainfall. Hence, its long term impact on this landslide disaster is also analyzed comparing with the slope destabilization due to strong seismic shaking.

2. Method and target areas
Field investigation on landslides slopes, slope failures and torrents where debris flows occurred are conducted to obtain the geologic data, geo-structure, vegetation feature, soil samples and topographic data i.e. cross sections, then soil shear tests and soil permeability tests are also conducted. The rainfall data at the nearest rain observatory were obtained from the database of Japan meteorological agency. The long term impact on the slope stability at some slopes in the area is analyzed by the finite element method (FEM) combined with rain infiltration and seepage analysis with the long term rainfall fluctuation data, obtaining factor of safety (Fs) on real landslide slopes. The results are compared with the destabilized influence on the slopes due to the soil strength reduction by seismic shaking.
The target areas are located in northern Kyushu district, western Japan where they often have severe landslide disasters. The geology in research areas consists of Paleozoic and Mesozoic rocks (mainly schist, slate) and Quaternary volcanic sediment such as Aso volcano body. The vegetation consists of mainly Japanese cypress, cedar or bamboo.

3. Result and consideration
Consequently, the long term rainfall increase in the region such as increment of approximately 20 mm/hr for rain intensity Ri in 36 years is confirmed statistically using Kendall's rank correlation, and it is found that its impact on slope stability is considerable and critical in other cases. In the sample landslide slopes, even the increase in rain of duration for only 10 years has impact to a certain extent on their stabilities in terms of Fs. The Fs calculated with rains in previous decade is higher than 1.0 that corresponds to stable state, whereas the Fs with present rains is lower than 1.0 such as 0.99 which means unstable state. Extremely heavy rainfall with this impact is generally cause extreme ground water pressure in the slope. It is also obvious that the extreme ground water content rendered even small landslides liquefied to be source of destructive debris flows. In this disaster, especially in the Aso volcanic region, tremendous number of debris flow occurred and even the talus cone slopes which are usually stable collapsed to flow down. However, the influence of the long term rainfall increase on the slopes (such as 1% decrease in Fs) is not relatively small compared with the destabilization of the slopes due to the reduction of soil strength by seismic shaking (8∼9 % reduction in Fs after seismic shaking of even 490gal).

4. Conclusion
In the disaster in July 2012, many landslides and debris flows originated from landslides induced by concentrated

underground water supplied by the heavy rainfall occurred.
The increase of rainfall due to climate change with the increasing rate such as 20 mm/hr surely has impact on almost landslide slopes in aspects of slope stability, although the influence of the long term rainfall increase on the slopes is relatively small compared with the destabilization of the slopes due to the reduction of soil strength by seismic shakings. Therefore, with this rain increase rate, it is possible for many forest slopes or natural slopes to become unstable and cause landslide disasters especially after potential strong earthquake in the near future.