Influences of Increasing Maximum Hourly Rainfall to Slope Stability in Aso City and Yame City, Japan

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Introduction

In a country with high density population and mountainous topographical setting such as Japan, the quantification of rainfall influences to landslide event is of importance. The increasing rainfall pattern that might be induced by climate change is being observed worldwide and being studied for its influence on triggering landslides,. This phenomenon is especially obvious in the northern part of Kyushu Island, Japan. (Kubota, 2010). Rainfall is the major agent in triggering landslides, it is more frequent compared to earthquake and slope undercutting (Crozier, 1986).

In July 2012, the city of Aso and the city of Yame experienced extreme heavy rainfall counting up to 106 mm/hr and 91 mm/hr. This heavy rainfall claimed casualties of more than twenty lives. The immediate result of heavy rainfall in these regions took the form of numerous landslides and debris flows.

The main objectives of this research are to evaluate the increasing maximum hourly rainfall pattern and intensity in Aso and Yame throughout the last decades and to evaluate the effect of increasing maximum hourly rainfall intensity and pattern on factor of safety (FS) in forest area of Aso and Yame.

Study site and methodology

The study sites are located in two prefectures of Japan, the first one is in Kumamoto Prefecture and the second one is in Fukuoka Prefecture. The average rainfall for Aso and Yame Region is 2831 mm/yr and 2018 mm/yr with most rain occurs in July. Field investigations were conducted on three slopes in Aso and one slope in Yame during the year of 2012 - 2013 to collect data from the field.

Rainfall increasing trends were statistically investigated using Mann-Kendall rank correlation and Sen's slope estimator in order to obtain the rate of increasing rainfall trends. Numerical analysis (Finite Element Method) was employed in this study to study the influences of increasing rainfall to forest slope stability. The FEM slope stability analysis was coupled with seepage analysis. Three different analyses were being simulated using FEM, the without rainfall effect, under the effect of actual rainfall of July 2012 (the rain of July 2012 is assumed to be under the influences of increasing rainfall trends), and without increasing rainfall (peak value of each rain event is reduced by the increment rate of increasing rainfall trend).

Result and Discussion

Rainfall data were collected to then be subjected in the Mann-Kendal test and Sen's slope estimation. Based on the obtained result, the increasing trends of maximum hourly rainfall were detected in both Aso-Otohime and Yame-Kurogi.

In Aso-Otohime, the increment rate of maximum hourly rainfall per year is 0.52 mm/hr. This means that during 1978 – 2012

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a total increment of 18.2 mm is happened in Aso-Otohime in term of maximum hourly rainfall. For the Yame-Kurogi case, the increment rate of maximum hourly rainfall per year is 0.48 mm. This means that during 1976 – 2012 a total increment of 17.76 mm is happened in Yame-Kurogi in term of maximum hourly rainfall.

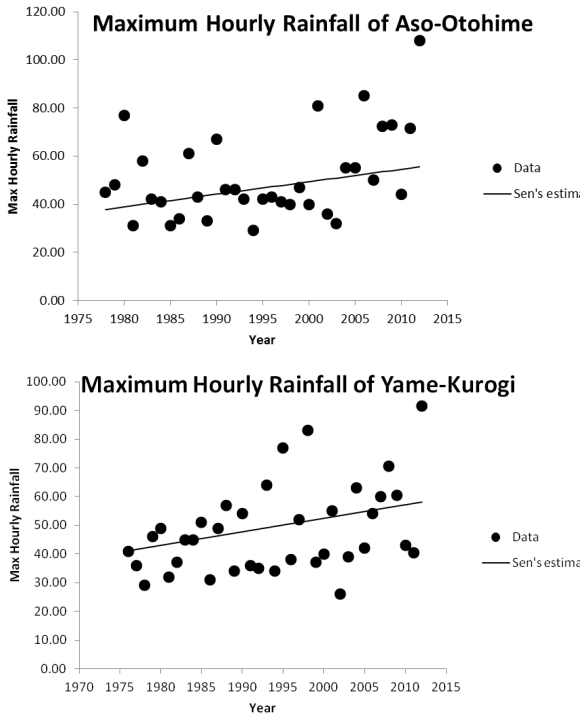

Fig 1. Trends in maximum hourly rainfall Aso-Otohime (top) and Yame-Kurogi (bottom)

The factor of safety (FS) of all slopes without rainfall effect are greater than 1.00, which denote that without any rainfall all slopes are in stable condition. All studied slopes FS were reduced on the event of July 2012 (FS<1.00), which means that the slope is prone to landslide, however without increasing rainfall, the slopes of Aso are stable (FS>1.00). On the other hand, the slope of Yame is experiencing failure (FS<1.00) under the effect of July 2012 rainfall and without the increasing rainfall trends, this might be due to its hydraulic properties which promotes greater permeability.

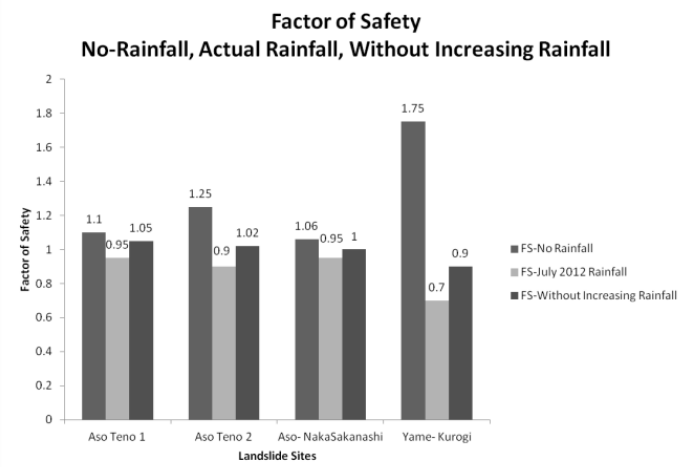

Fig 2. Factor of Safety (no-rainfall, actual rainfall, without increasing rainfall).

Conclusion

Based on the obtained result, the following conclusion is presented. Firstly, the increasing trend of maximum hourly rainfall is statistically detected in Aso city and Yame city. The maximum hourly rainfall during 1978-2012 (Aso) and 1976-2012 (Yame) are increased 18.2 mm/hr and 17.6 mm/hr at the rate of 0.52 mm/hr/yr and 0.48 mm/hr/yr. Secondly, the increase of maximum hourly rainfall is surely has negative influences in term of slope stability. Therefore, under this increasing rainfall rate, it is possible for many forest slopes to become unstable and prone to landslide disaster in the near future.

References

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