Influence of Long-Term Increasing Trend of Maximum Hourly Rainfall on Slope Stability in Forested Area of Aso, Japan

Aril ADITIAN[1*] and Tetsuya KUBOTA[2]

INTRODUCTION

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 2012, the city of Aso in western Japan experienced heavy rainfall from July 11 to July 13 counted up to 656 mm with the intensity of 493 mm/day and 106 mm/hr. This tremendous amount of rainfall translated into countless traces of debris flows and landslides. By employing numerical analysis (Finite Element Method), this study aims to quantify the increasing rainfall in the city of Aso throughout the last decades and its effects to slope stability in forest area.

METHODS

Study Site

The study site is located in the Kumamoto Prefecture, Japan. The city of Aso experienced numerous landslides and debris flows during the record-breaking rainfall on July 2012. Three slopes were taken as case studies for the influence of increasing rainfall induced by climate change on the forest slope stability. The average annual rainfall of the study site is 2831 mm/year (Japan Meteorological Agency, 2013) with most rainfalls on June and July.

Methodology

Soil samples were collected from the field to be subjected to shear and permeability test in the laboratory. Climate data were collected from Japan Meteorological Agency (JMA), data were collected through the Automated Meteorological Data Acquisition System (AMeDAS) network from the Aso-Otohime weather station. Rainfall data were collected during the period of 1978 – 2012. Trends in increasing rainfall were then statistically analysed using Mann-Kendall's rank correlation to get estimated value of increasing rainfall throughout the decades.

In this study, the slope stability analysis was performed using FEM with strength reduction technique. The soil was modelled according to Mohr-Coulomb failure criterion for its mechanical properties and Van Genuchten Model for its hydraulic properties. GUSLOPE Ver 1.00 computer code was employed in this study. FEM were conducted with three different scenarios:

- No Rainfall
- Actual Rainfall of July 2012
- Without Increasing Maximum Hourly Rainfall (reduce the peak value of each rain event by the rate of increment according to sen's slope estimator)

1 Laboratory of Forest Conservation and Erosion Control, Kyushu University (Hakozaki 6-10-1, Higashi-ku, Fukuoka, 812-8581 Japan)
2 Dept. Forest Environment Science, Faculty of Agriculture, Kyushu University (Hakozaki 6-10-1, Higashi-ku, Fukuoka, 812-8581 Japan)
*Corresponding author. E-mail: aril@kyudai.jp

RESULTS

In the case of maximum hourly rainfall, the increasing trend is detected at 0.01 level of significance. It is obtained that the increasing value of the yearly maximum hourly rainfall is 0.52 mm/hr/year, this means that during 1978 – 2012 a total increment of 18.2 mm/hr is happened in Aso-Otohime in term of maximum hourly rainfall.

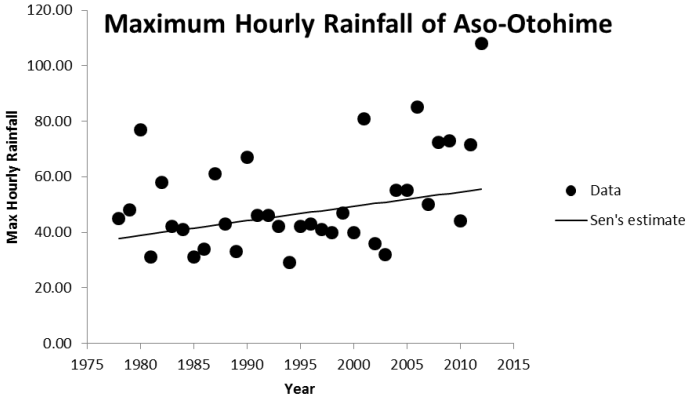

Fig 1. The long term increasing trend of maximum hourly rainfall in Aso-Otohime.

All studied sloped showed stable condition when simulated to no rainfall scenario. Aso Teno 1 (FS 1.10), Aso Teno 2 (FS 1.25), and Aso-Nakasakanashi (FS 1.06), However all slopes experiences failure when being simulated to the heavy rainfall event of July 2012: Aso Teno 1 (FS 0.95), Aso Teno 2 (FS 0.90), and Aso Nakasakanashi (FS 0.95). Under the scenario of without increasing rainfall, all Aso slopes are in stable condition. FS increase slightly above the safety threshold of 1.00. : Aso Teno 1 (FS 1.05), Aso Teno 2 (FS 1.02), and Aso Nakasakanashi (FS 1.00). It can be implied that if there is no increasing rainfall effect (that might be induced by climate change) the slopes of Aso are in stable condition.

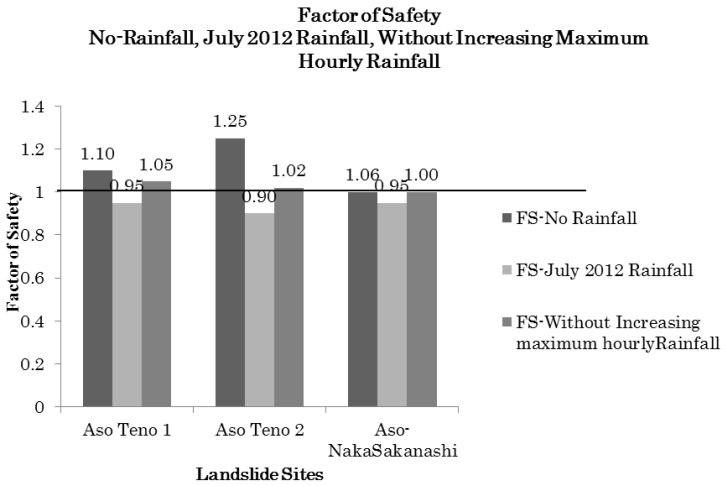

Fig 2. Factor of Safety with three different scenarios (No rainfall, July 2012 rainfall, without increasing rainfall)

CONCLUSIONS

Based on the presented data, the following conclusions are 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) are increased 18.2 mm/hr at the rate of 0.52 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.

Keywords: Rainfall, Slope Stability, Finite Element Method