Relationship between Rainfall and Landslides in Shirasu Areas of Kagoshima, Japan

鹿児島県シラス地帯の斜面崩壊と降雨の関係

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1. Introduction

Landslides are one of most serious problems that cause enormous damage to the people and life in Kagoshima. Shirasu is the geological formation in Kagoshima in which the most landslides occur. Catastrophic landslide disasters have occurred through time and Shirasu landslides have killed many people. Kagoshima is attacked by heavy rainfall every year and landslides are triggered by heavy rainstorms, baiu fronts and typhoons.

2. Objectives

In this study, I evaluate the relationship between precipitation variables and landslide occurrence in Shirasu areas of Kagoshima Prefecture and use these findings as a yardstick for preparing for landslide disasters. I focused on the effect of antecedent precipitation index (API).

3. Methodology

Landslides that had clear occurrence times were selected from the database of Kagoshima prefecture. The digital map with landslide locations was overlaid on an engineering geological map of Kagoshima Prefecture to select which landslides occurred in Shirasu areas. All together 184 Shirasu landslides with full information (accurate dates, times and locations) were chosen from the total of 1153 landslides recorded from 1985 to 2005. The observatories, which have rainfall data, should be within 5 km from the landslide location. Multiple Regression Analysis was used to evaluate relationships between rainfall characteristics and Shirasu landslides.

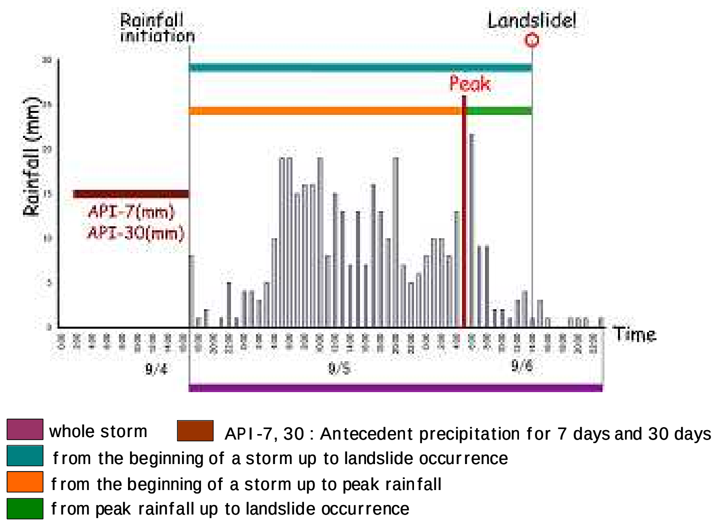

Fig.1 Rainfall characteristics that triggered typical

4. Results of Multiple regression analysis

During high intensity rainfall (≧5mm/h), API-7 and ppt P-L are important factors that trigger Shirasu landslides (Fig.2). Both of these affect the ppt as well as the drn B-L. When API-7 is larger, ppt and the drn B-L becomes smaller and shorter. On the other hand, low intensity rainfall (< 5mm/h), API-30 and drn P-L are important factors that trigger Shirasu landslides. Both of these affect ppt and the drn B-L. When API-30 is larger, ppt and the drn B-L become smaller and shorter. Longer duration P-L makes the amount of ppt B-L larger.

5. Conclusion and Discussion

There are two types of rainstorms that trigger Shirasu landslides. The types are; high intensity rainstorms and low intensity rainstorms.During high intensity rainstorms, total precipitation and the duration from the beginning of a storm up to landslide occurrence is affected by API-7. When API-7 is larger, total precipitation and the duration from the beginning of a storm up to landslide occurrence becomes smaller and shorter. In addition, average intensity from the beginning of a storm up to landslide occurrence affects the duration from the beginning of a storm up to landslide occurrence during high intensity rainfall. When the average intensity from the beginning of a storm up to landslide occurrence is larger, duration from beginning of a storm up to landslide occurrence becomes shorter. High intensity and shorter duration storms together with either greater total precipitation or high API-7 appear to influence initiation of shallow landslides by pore water pressure.

Average intensity from beginning of a storm up to landslide occurrence ≧ 5 mm/h
(Short duration and high intensity rainfall)

Equation	c-p	F	P	R-Sq
ppt B-L = 2.67 - 0.110 API-7 + 0.673 MAX 1-h + 0.185 ppt P-L	4.6	25.29	< 0.001	45.5
p 0.001 0.000 0.000				
drn B-L = 3.34 - 0.101 API-7 - 1.22 Avg B-L + 0.665 MAX 1-h + 0.178 ppt P-L	4.8	31.59	< 0.001	58.4
p 0.001 0.000 0.000 0.000				

Average intensity from beginning of a storm up to landslide occurrence < 5 mm/h
(Long duration and low intensity rainfall)

Equation	c-p	F	P	R-Sq
ppt B-L = 1.54 - 0.221 API-30 + 1.56 Avg B-L + 0.663 MAX 1-h + 0.211 drn P-L	4.4	42.36	< 0.001	66.9
p 0.001 0.000 0.000 0.000				
drn B-L = 2.60 - 0.198 API-30 + 0.649 MAX 1-h + 0.190 drn P-L	2.1	20.99	< 0.001	42.6
p 0.001 0.000 0.000				

ppt B-L, drn B-L; total precipitation (mm) and the duration (h) from beginning of a storm up to landslide occurrence
ppt P-L, drn P-L; total precipitation (mm) and the duration (h) from peak precipitation up to landslide occurrence
Avg B-L; average intensity (mm/h) from begimning of a storm up to landslide occurrence
MAX1-h: Maximum 1-h precipitation (mm/h)

Fig2. Results of multiple regression analysis

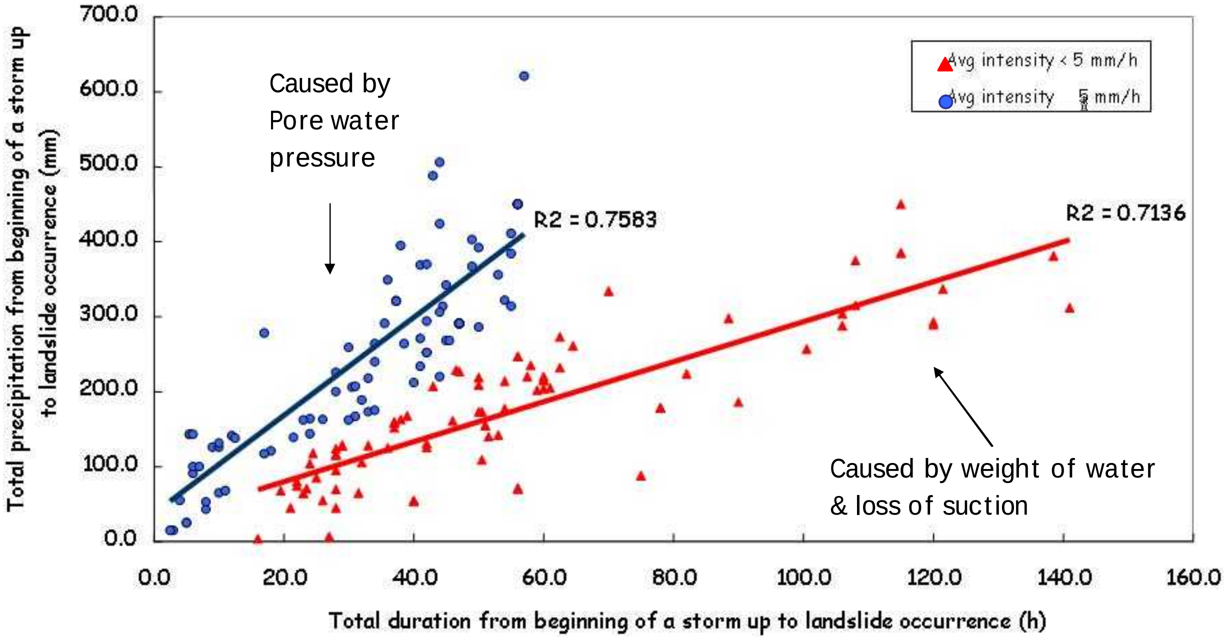

Fig3 Relationship between Total precipitation & the duration from beginning of a storm up to landslide occurrence

On the other hand, during low intensity rainstorms, API-30 affects total precipitation and the duration from the beginning of a storm up to landslide occurrence. When API-30 is larger, total precipitation and the duration from the beginning of a storm up to landslide occurrence become smaller and shorter. In addition, average intensity from the beginning of a storm up to landslide occurrence affects total precipitation required to initiate a landslide during low intensity rainstorms. When average intensity from beginning of a storm up to landslide occurrence is larger, total precipitation from the beginning of a storm up to landslide occurrence becomes larger. Low intensity and longer duration storms with less total precipitation and higher API-30 may cause deeper landslides by reduction of suction and increasing weight of infiltrated water. In addition, these landslides may be deeper failures.