論 文

海岸林学会誌（*Journal of the Japanese Society of Coastal Forest*）8（2）：86 − 91, 2009

Characteristics of slope failure in the western hillside of Yakushima

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Abstract: We studied the characteristics of slope failure and their temporal change by interpreting aerial photographs taken in May 1977, November 1990, and May 2004 of a granite basin on the island of Yakushima, in Kagoshima prefecture, Japan. Shallow landslides and deep-seated landslides were observed. The total areas of slope failures for the May 1977, November 1990, and May 2004 observations of the basin were about 0.075, 0.049, and 0.128 km^2 respectively. The aerial photographs taken in May 2004, for which the number of prior heavy rain days was the greatest of the three study periods, showed the highest total area of slope failure. The percentage area of slope failure was greatest for a slope inclination of 40 degrees or more.

1 Introduction

The island of Yakushima is 130 km south of mainland Kagoshima prefecture, Japan. The island has a circumference of 105 km and an area of 500 km^2. Mountains with summits not less than 1000 m above sea level are located in the central part of the island. The average annual rainfall is about 4000 mm in the lowlands and not less than 8000 mm in the mountainous regions.

Many slope failures and associated debris flows are generated on steep slopes and in channels on the island. These slope failures and debris flows frequently cause sediment-related disasters; for example, that due to heavy rainfall in 1982 (Shimokawa and Iwamatsu, 1982, 1983). Shimokawa and Jitousono (1997) estimated the time interval between occurrences of slope failure on the same slope as approximately 1000 to 1500 years from a field survey in the northwestern region of Yakushima and on the basis of dendrochronological analysis of *Cryptomeria japonica*.

Development of the coast on Yakushima is closely concerned with sediment yield and discharge in the upper reaches of the coast. Debris flows caused by large-scale slope failures might lead to a large-scale change of the coast. Clarifying the features and its temporal changes of the occurrence of slope failure on Yakushima is considered to lead to conservation of the coast and the coastal forest on Yakushima.

The purpose of this study is to clarify the characteristics of slope failure and their temporal changes from the interpretation of aerial photographs of a granite basin on Yakushima. Moreover, we investigated the effects of slope inclination and rainfall on the occurrence and scale of slope failure.

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2 Study basin and methods

The study basin is located on the western side of Yakushima (Figure 1). The basin has an area of 11.9 km^2 and an altitude ranging from 0 to 1323 m above sea level. The drainage density of the basin was calculated using a 1/25000 topographical map drawn up by the Geographical Survey Institute. The drainage system was divided using Strahler's method. The drainage density of the basin was 9.1 km/km^2.

The slope inclination of the basin was also calculated using the 1/25000 topographical map, and the basin was divided into areas of slope inclinations in 10 degree intervals. The inclination chart we produced shows that 2% of the total area had an inclination less than 10 degrees, 5% had an inclination from 10 to 20 degrees, 6% had an inclination from 20 to 30 degrees, 58% had an inclination from 30 to 40 degrees, and 29% had an inclination greater than 40 degrees. Thus steep slopes of not less than 30 degrees accounted for about 90% of the total area.

The geology of the study basin consists of granite that occupies much of the island and sedimentary rock that occupies part of the lower reach of the island (Kagoshima prefecture, 1990). The vegetation of the study basin consists of laurel forest that occupies much of the middle and lower reaches of the island and coniferous trees that occupy part of the upper reaches of the island.

Aerial photographs were used to clarify the characteristics of slope failure and their temporal changes in the study basin, and a distribution chart detailing slope failures and debris flow scars was produced. Three pairs of aerial photographs taken in May 1977, November 1990, and May 2004 were used for the analysis. Furthermore, we investigated the form, geomorphological features, and scale of the slope failures as well as rainfall responsible for slope failure in the basin. Rainfall responsible for the occurrence of slope failure was defined as that falling on a day on which no less than 100 mm of rain fell. The study periods for the rainfall analysis were from October 1963 to May 1977 for the aerial photograph taken in May 1977, from June 1977 to November 1990 for the photograph taken in November 1990, and from December 1990 to May 2004 for the photograph taken in May 2004. Rainfall data used in the analysis of the occurrence of slope failure were recorded by an automated meteorological data acquisition system, which ran from 1963 to 2004 in the town of Yakushima.

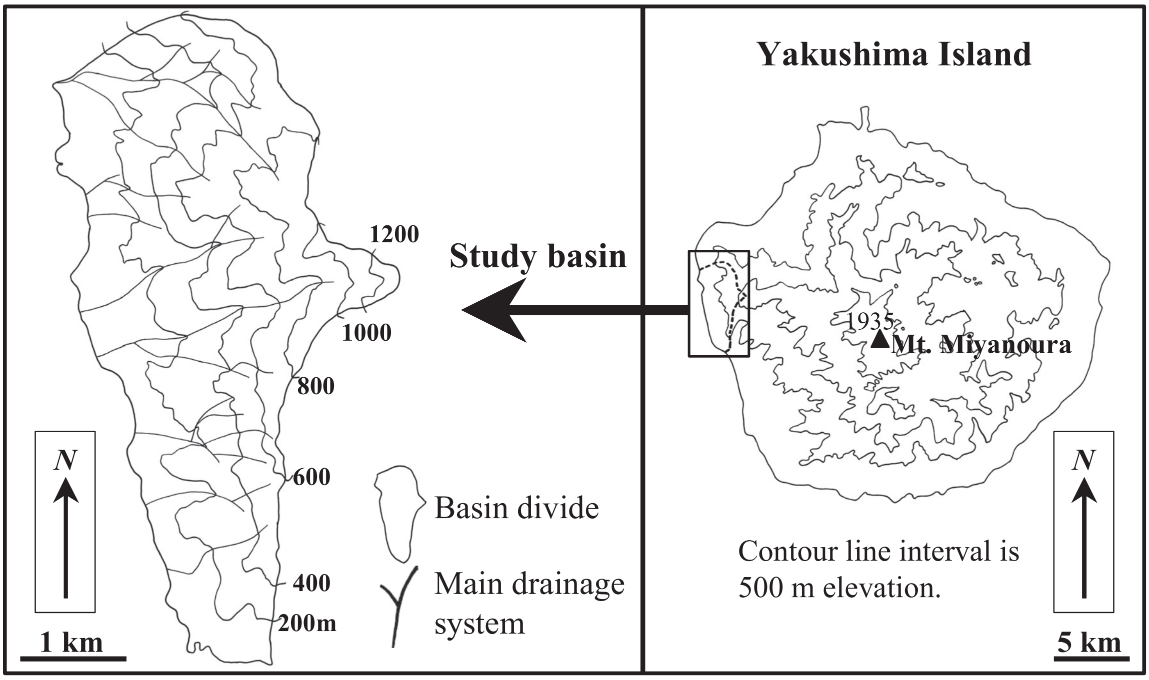

Figure 1: Location of the study basin

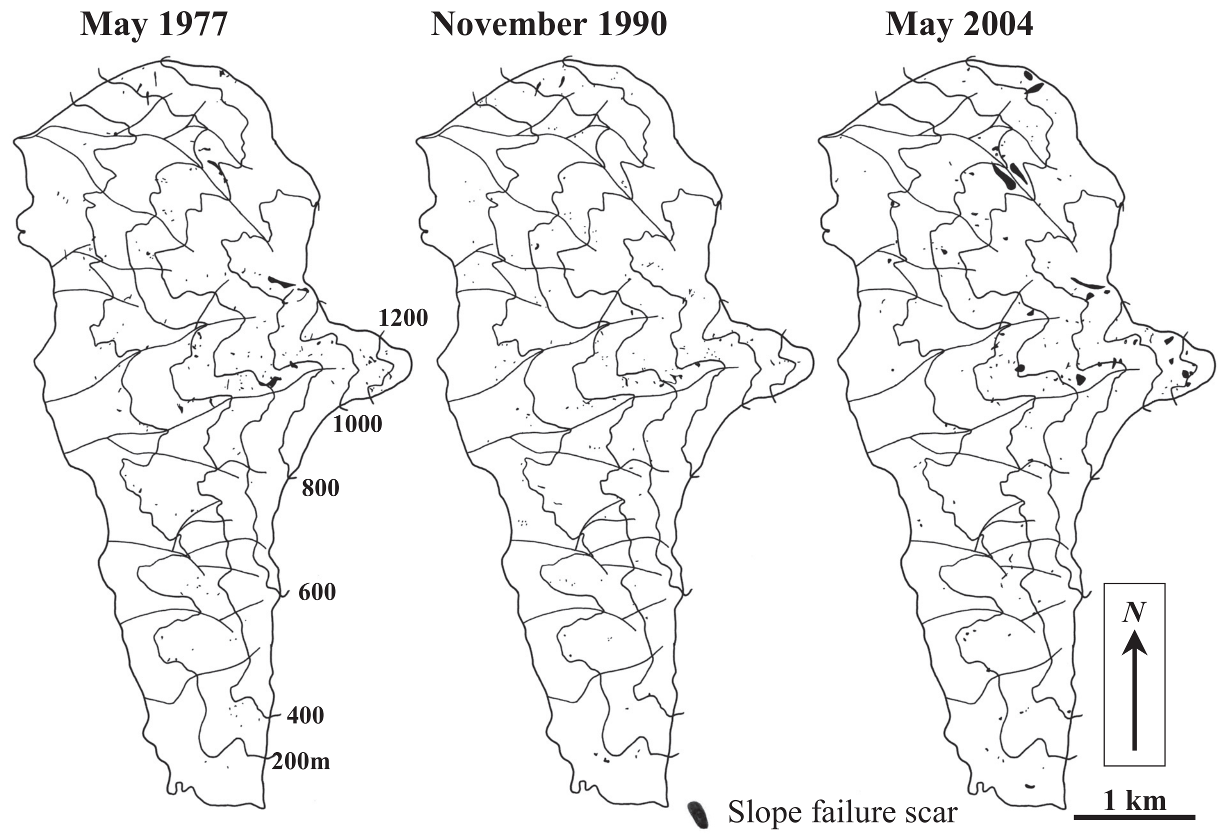

Figure 2: Distribution charts of the slope failures and debris flow scars from the interpretation of aerial photographs

3 Results and discussion

3.1 Distribution and scale of slope failure

Figure 2 shows distribution charts of the slope failures and debris flow scars from the interpretation of aerial photographs of the study basin taken in May 1977, November 1990, and May 2004. Many slope failures were distributed on steep slopes in the basin, and they were seen to have debris flows among them. We detected 194, 188, and 169 slope failures in the basin for May 1977, November 1990, and May 2004 respectively. Shallow landslides resulting from the infiltration of rain water into surface soil and its concentration in the cutting and natural slopes as well as deep-seated landslides resulting from the infiltration of rain water into surface soil and bedrock and its concentration in natural slopes were observed.

Figure 3 shows frequency distributions of the areas of slope failures calculated from distribution charts of the slope failures scars for May 1977, November 1990, and May 2004. About 70% of the slope failures for November 1990 had areas not more than 1000 m^2. On the other hand, more than 50% of the slope failures for May 1977 and May 2004 had areas not less than 1000 m^2. The areas of slope failures for May 1977 ranged from 16 to 7169 m^2 and had an average of 388 m^2, those for November 1990 ranged from 8 to 5207 m^2 and had an average of 259 m^2, and those for May 2004 ranged from 56 m^2 to 15943 m^2 and had an average of 758 m^2. The sums of the areas of slope failures for May 1977, November 1990, and May 2004 in the basin were about 0.075, 0.049, and 0.128 km^2 respectively. The percentage areas of slope failures for May 1977, November 1990, and May 2004 were about 0.6%, 0.4%, and 1.1%, respectively. Thus the total area of slope failure for May 2004 was greater than that for the other two observations.

3.2 Rainfall responsible for the occurrence of slope failure

Figure 4 shows frequency distributions of the daily rainfall being not less than 100 mm as recorded by the automated meteorological data acquisition system. The numbers of days for which the rainfall was not less than 100 mm were 99 in the period from October 1963 to May 1977, 89 in the period from June 1977 to November 1990, and 143 in the period from December 1990 to May 2004. Aerial photographs taken in May 2004, for which the number of prior rainy days was the greatest, showed the greatest total area of slope failure for slope failures not less than 1000 m^2 in size.

3.3 Occurrence of slope failure and slope inclination

Figure 5 shows frequency distributions of the percentage area of slope failure divided by slope inclinations in 10-degree intervals. The percentage area of slope failure for inclinations of 40 degrees or more was greater than percentage areas for other slope inclinations. Shimokawa and Jitousono (1997) conducted a field survey of the slope inclination for occurrences of slope failures in a granite basin on Yakushima. They reported that many of the slope failures had occurred on steep slopes of not less than 40 degrees and thus their results agree with those of the present study.

4 Conclusions

The results of the present study are as follows.

(1) The distribution and form of slope failures in a study basin composed of granite were investigated. Many slope failures were distributed on steep slopes and seen to have debris flows among them. Shallow landslides in the cutting and natural slopes and deep-seated landslides in natural slopes were observed.

(2) Areas of slope failures in the study basin were investigated. The area of slope failures for May 1977 ranged from 16 to 7169 m^2 and had an average of 388 m^2, that for November 1990 ranged from 8 m^2 to 5207 m^2 and had an average of 259 m^2, and that for May 2004 ranged from 56 m^2 to 15943 m^2 and had an average of 758 m^2. The total areas of slope failures in May 1977, November 1990, and May 2004 in the basin were about 0.075, 0.049, and 0.128 km^2 respectively.

(3) The relationship between rainfall responsible for the occurrence of slope failure and the scale of slope failure was investigated. Aerial photographs taken in May 2004, for which the number of prior heavy rain days was the greatest, showed the greatest total area of slope failure for slope failures not less than 1000 m^2 in size.

(4) The relationship between the occurrence of slope failure and the slope inclination was investigated. The percentage area of slope failure was greatest for a slope inclination of 40 degrees or more.

Acknowledgments

The authors would like to express their appreciation of the cooperation of Haruka Yazawa, a student of the Erosion Control Engineering and Forest Hydrology Laboratory at the Faculty of Agriculture, Kagoshima University.

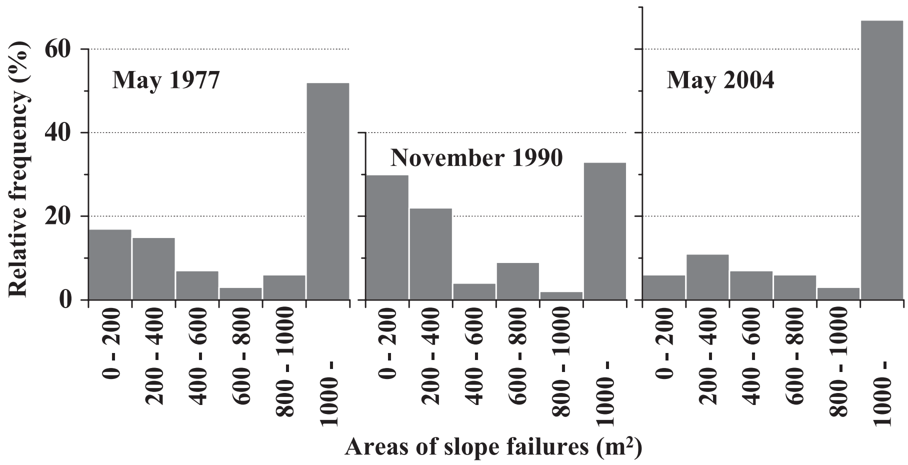

Figure 3: Frequency distributions of the areas of slope failures calculated from distribution charts of the slope failure scars

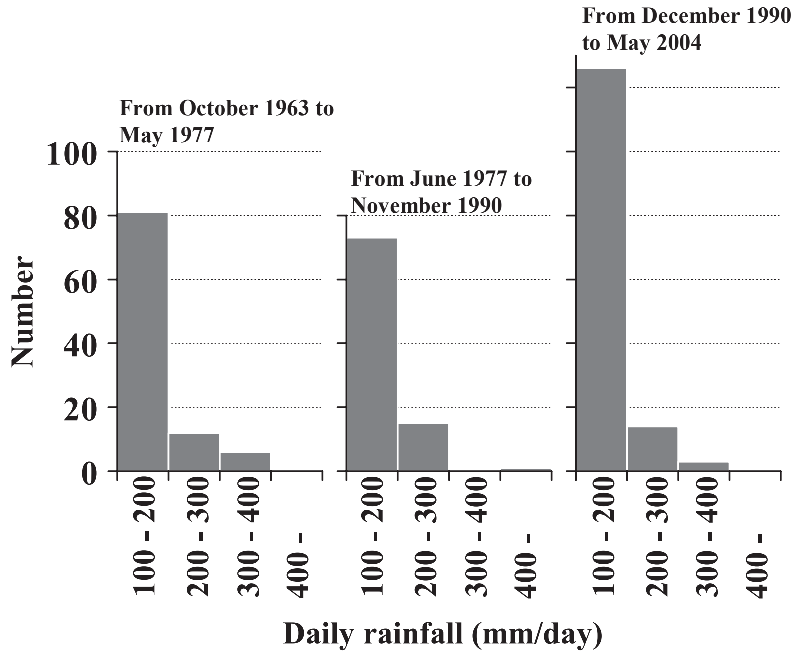

Figure 4: Frequency distributions of daily rainfall not less than 100 mm recorded by an automated meteorological data acquisition system in the town of Yakushima

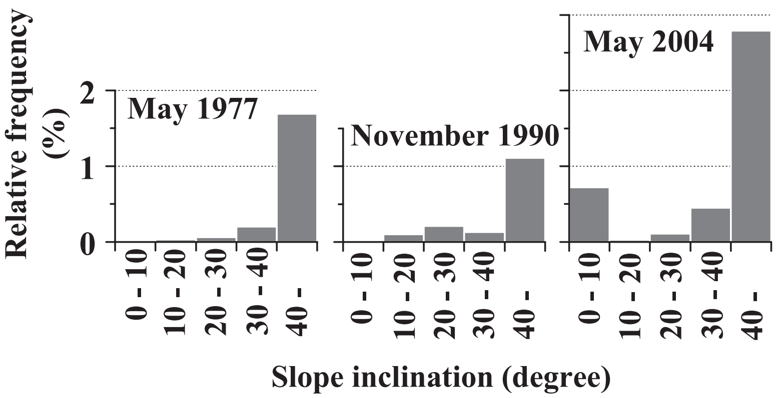

Figure 5: Frequency distributions of the ratio of the areas of slope failures divided into slope inclinations in 10 degree intervals

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〔Received February 26th,2009 Accepted November 25th,2009〕